Missouri Department of Natural Resources
Water Protection Program

Total Maximum Daily Loads (TMDLs)

for

Hickory Creek
Daviess County, Missouri

Completed: June 2, 2010
Approved:

Total Maximum Daily Load, or TMDL
for Hickory Creek
Pollutant: Unknown

Name: Hickory Creek

Location: Daviess County near Jameson and Coffey, Mo.

Hydrologic Unit Code (HUC): 10280101-160002

Water Body Identification (WBID): 442

Missouri Stream Class: C[1]

Designated Beneficial Uses:
- Livestock and Wildlife Watering
- Protection of Warm Water Aquatic Life
- Protection of Human Health (Fish Consumption)

Use that is impaired: Protection of Warm Water Aquatic Life

Location of Impaired Segment: Mouth to Section 11, T60N, R28W

Length of Impaired Segment: 1.5 miles[2]

Pollutant: Unknown

Source: None given

TMDL Priority Ranking: Medium

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[1] Class C streams may cease flow in dry periods but maintain permanent pools which support aquatic life. See the Missouri water quality standards, or WQS, at 10 Code of State Regulations (CSR) 20-7.031(1)(F). The standards can be found online at www.sos.mo.gov/adrules/csr/current/10csr/10c20-7.pdf

[2] Effective Oct. 30, 2009, 10 CSR 20-7.031 Table H now lists the length for this segment as 2.8 miles.

1. Introduction and Background Information

This Hickory Creek Total Maximum Daily Load (TMDL) is being established in accordance with Section 303(d) of the Clean Water Act. This water quality limited segment near Jameson, Mo. in Daviess County is included on the U.S. Environmental Protection Agency (EPA) approved Missouri 2008 303(d) List of impaired waters with the pollutants of concern listed as unknown.

The purpose of a TMDL is to determine the pollutant loading a water body can assimilate without exceeding the water quality standards for that pollutant. The TMDL also establishes the pollutant load allocation necessary to meet the Missouri water quality standards established for each water body based on the relationship between pollutant sources and in-stream water quality conditions. The TMDL consists of a wasteload allocation, a load allocation, and a margin of safety. The wasteload allocation is the portion of the allowable pollutant load that is allocated to point sources. The load allocation is the portion of the allowable pollutant load that is allocated to nonpoint sources. The margin of safety accounts for the uncertainty associated with the model assumptions and data inadequacies. The model used to derive these TMDLs was completed by the EPA.

There are several Hickory Creeks in Missouri. This water quality limited segment lies in northwest Missouri, in north central Daviess County. The classified segment is listed as 1.5 miles long (see footnote #2, preceding page) and flows southwest and west before joining the Grand River about three miles northwest of Jameson. The Hickory Creek watershed area is 20.9 square miles with the upper most part of the watershed, which encompasses 5.2 square miles, in Harrison County to the north.

Per Missouri's Water Quality Standards regulation at 10 CSR 20-7.031, classified waters of the state must attain the Protection of Warm Water Aquatic Life designated use where designated. The combination of natural geology, topography, and land use in the former prairie region of the state where Hickory Creek is located is believed to have reduced the amount, and impaired the quality, of habitat for aquatic life. The creek was first documented as impaired during the Department's Visual/Benthic Low Flow Surveys in July 2000 and was reported in the revised "Monitoring Report on 26 Waters" (EPA 2003a). Evidence of impairment was primarily narrative rather than numeric, as indicated by the presence of duckweed and dense filamentous algae. These observations supported the case that nutrient enrichment was negatively impacting the stream. "Rocks darkened by manganese," which may indicate anoxic conditions, were also noted. However, no numeric data was collected to support the listing. In 2006-07, Versar, Inc., under contract to EPA, conducted a stressor identification study on the creek and found the aquatic community was impaired (Table 1). This study identified the stressors, or possible causes of impairment, as low dissolved oxygen levels, increased silt and sediment in the stream, poor habitat quality and low or altered flow regime. For more discussion of the study results, see Section 2.2.5. An additional study on Hickory Creek was conducted in 2008-09 by the department's Environmental Services Program, or ESP, examining both the aquatic invertebrate community and water quality parameters. When compared to bioreference streams, these sites showed no biological impairment during 2008-09. However, these were notably wet years, with more rainfall than normal.

Table 1. Stream Condition Scores for Hickory Creek

Org	Site	Date	Score
Versar Inc.	Hickory Cr.- 1	Fall 2006	14
Versar Inc.	Hickory Cr.- 1	Spring 2007	12
Versar Inc.	Hickory Cr.- 1	Fall 2007	10
Versar Inc.	Hickory Cr.- 2	Spring 2007	4
MDNR	Hickory Cr.- 2	Fall 2008	16
MDNR	Hickory Cr.- 2	Spring 2009	18
MDNR	Hickory Cr.- 3	Fall 2008	20
MDNR	Hickory Cr.- 3	Spring 2009	18

Scores of 16 or greater indicate no impairment. See Figure 2 for site locations.

1.1 Soils

The soils in the Hickory Creek watershed fall into three main associations (USDA 1964). The Wabash-Nodaway association is found in the floodplain. The Nodaway soils are mainly well-drained, fine, sandy loam to silt loam. The Wabash soils are darker, contain more clay, and are more poorly drained. The soils of the Gara series have a moderately dark colored surface soil and are moderately well drained. These soils occur primarily on gentle to strong slopes where timber has encroached upon prairie. Most of the original surface soil has been lost to erosion from the Gara series acreage. The Grundy-Seymour association is on gently rolling to strongly rolling hills, with poorly to moderately well-drained soils formed from loess or till.

1.2 Land Use

Recent land use data for the Hickory Creek watershed indicates that 38.8 percent of the watershed is classified as grassland (which can include pastures), 35.9 percent is cropland and 21.6 percent is forest and woodland (Table 2 and Figure 1). Although only part of one town (population 140) is in the watershed, 2.9 percent is classified as urban and includes impervious surfaces like county roads and rooftops of large structures. Table 3 presents land use statistics within the Hickory Creek watershed by county (Daviess and Harrison). As shown in Figure 1, Hickory Creek is over 12 miles in length with only the lower 1.5 classified miles being listed as impaired.

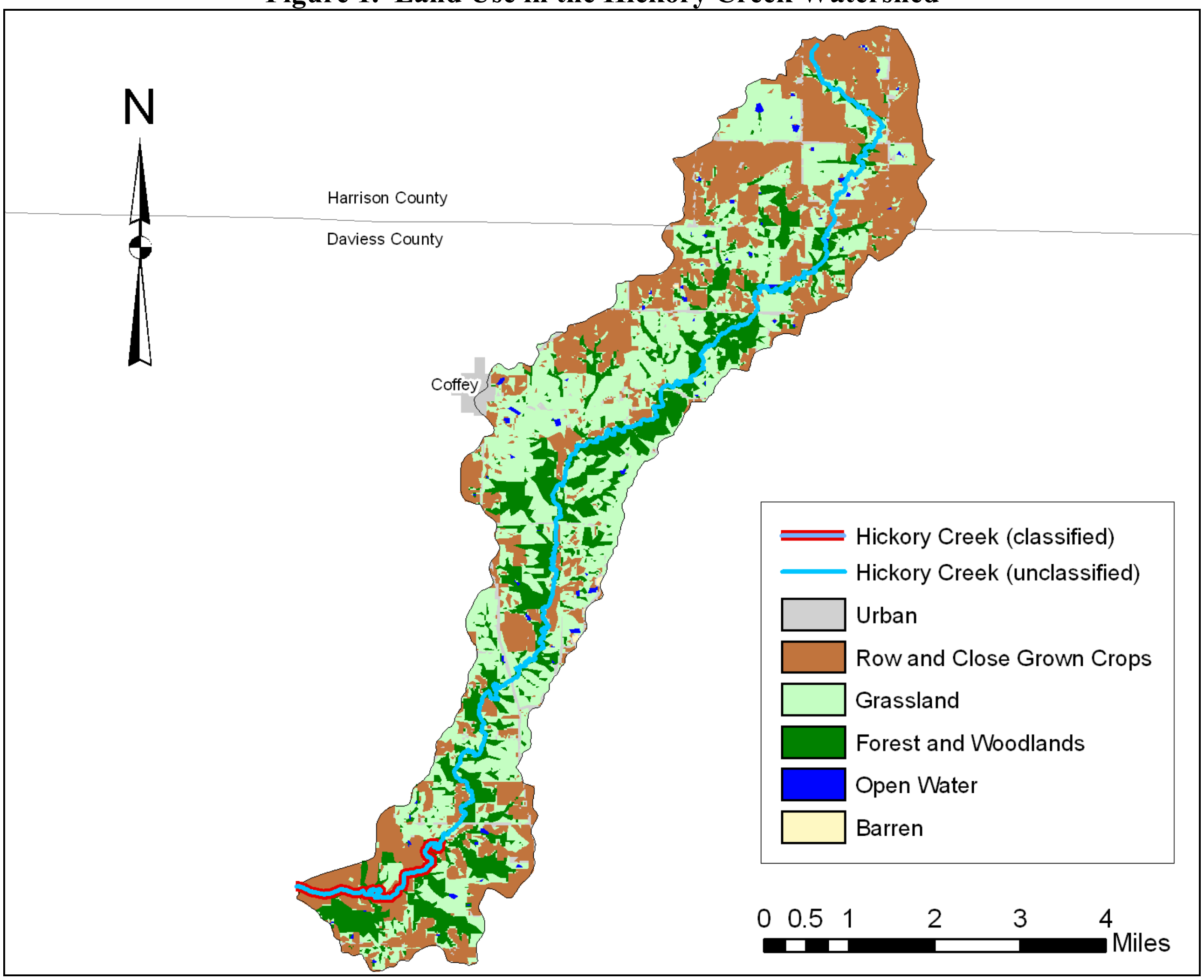
Table 2. Land Use/Land Cover in the Hickory Creek Watershed (MoRAP 2005)

Land Use Type	Area - Acres	Area - Sq. Miles	Percentage
Urban	391	0.61	2.9
Row and Close-grown Crops	4,794	7.49	35.9
Grassland	5,191	8.11	38.8
Forest and Woodland	2,889	4.51	21.6
Open Water	91	0.14	0.7
Barren	10	0.01	0.1
Totals	13,366	20.87	100.0

Table 3. Land Use/Land Cover by County

Land Use Type	Daviess County			Harrison County		
	Acres	Square Miles	Percentage	Acres	Square Miles	Percentage
Urban	280	0.44	2.8	110	0.17	3.3
Row and Close-grown Crops	2,759	4.31	27.4	2040	3.19	61.7
Grassland	4,271	6.67	42.5	919	1.44	27.8
Forest & Woodland	2,675	4.18	26.6	212	0.33	6.4
Open Water	66	0.10	0.7	25	0.04	0.8
Barren	10	0.01	0.1	0	0.00	0.0
Totals	**10,061**	**15.72**	**100.0**	**3306**	**5.17**	**100.0**

Figure 1. Land Use in the Hickory Creek Watershed



1.3 Population

The population of the Hickory Creek watershed is not directly available; however, the rural population of the watershed can be estimated based on the proportion of the watershed that is located in Daviess and Harrison counties. The 2000 census data was used to conduct this analysis.

Daviess County covers an area of 563 square miles and has a population of 8,016. It incorporates eight towns (Altamont, Coffey, Gallatin, Jameson, Jamesport, Lock Springs, Pattonsburg and Winston) with a total urban population of 3,349. Since the rural population in Daviess County is 4,667 (total county population minus urban population) and the rural area of the Hickory Creek watershed in Davies County is approximately 15.72 square miles, the rural population of the watershed is estimated to be 130 (15.72 square miles divided by 563 square miles multiplied by 4,667 people).

Harrison County covers an area of 720 square miles and has a population of 8,850. It incorporates eight towns (Bethany, Blythedale, Cainsville, Eagleville, Gilman City, Mount Moriah, New Hampton and Ridgeway) with a total urban population of 5,413. Since the rural population in Harrison County is 3,437 (total county population minus urban population) and the rural area of the Hickory Creek watershed in Harrison County is approximately 5.17 square miles, the rural population of the watershed is estimated to be 25 (5.17 square miles divided by 720 square miles multiplied by 3,437 people).

2. Source Inventory

This section summarizes the available information on possible sources of pollution that could be impairing Hickory Creek. The two water quality studies show impairment of the aquatic community at low flow or drought conditions and a healthy aquatic community at higher flows. During both flow regimes, however, there are problems with excessive sedimentation and nutrients. These pollutants will be targeted by the TMDL (Section 3.5) and are the pollutants that will addressed by the source inventory. Point (or regulated) pollutant sources are presented first, followed by nonpoint (or unregulated) sources.

2.1 Point Sources

The term "point source" refers to any discernible, confined and discrete conveyance, such as a pipe, ditch, channel, tunnel or conduit, by which pollutants are transported to a water body. Point sources are typically those regulated through the Missouri State Operating Permit program[3]. By law, point source also includes concentrated animal feeding operations, or CAFOs, which are facilities where animals are confined and fed and storm water runoff from Municipal Separate Storm Sewer Systems (MS4s). The Hickory Creek watershed contains one permitted CAFO, but there may be other smaller animal feeding operations in the watershed that are too small to require a permit.

The permitted facilities in the Hickory Creek watershed are listed in Table 4 and displayed in Figure 2. There are two facilities with general permits and one with a site specific permit within the watershed. All of the discharge outfalls for Continental Grain's Campbell Creek Farm (MO-0118460) are in Gentry County and are not located in the Hickory Creek watershed. However, the facility does conduct water quality monitoring at several sites, including one on Hickory Creek identified as "outfall #15". General

[3] The Missouri State Operating Permitting program is Missouri's program for administering the federal National Pollutant Discharge Elimination System (NPDES) program

permits (as opposed to site specific permits) are issued to activities that are similar enough to be covered by a single set of requirements. The general permits found within the Hickory Creek watershed are listed in Table 4 and start with MOG. These facilities do not discharge to the impaired stream, but do have storm water runoff during rain events. Figure 2 and Table 5 present a map of Hickory Creek in Daviess County with sampling sites and permitted facilities and sampling site locations, respectively.

Table 4. List of Permits in the Hickory Creek watershed

Permit #	Facility Name	Type	Other	Design Flow	Expire Date	Receiving Stream	Receiving Stream Class
MO0118460	CGC CAMPBELL CREEK FARM	NON-MUNICIPAL	HOGS	0.4570	20090415	CAMPBELL CREEK*	U
MOG010475	HICKORY CREEK FARMS	AFO-CAFO	HOGS	0.0578	20110223	HICKORY CREEK	U
MOG640140	HARRISON COUNTY PWSD #2	NON-MUNICIPAL	WATER	NONE	20131023	TRIB TO HICKORY CK	U

*In Gentry County

2.2 Nonpoint Sources

Nonpoint sources include all other categories not classified as point sources. Nonpoint sources potentially contributing to the impairment by unknown pollutants in the Hickory Creek watershed include runoff from agricultural areas, runoff from urban areas, onsite wastewater treatment systems and various sources associated with riparian habitat conditions. Each of these is discussed further in the following sections, along with the stressors identified in the Versar study mentioned in Section 1.

2.2.1 Runoff from Agricultural Areas

Lands used for agricultural purposes can be a source of nutrients, oxygen-consuming substances and sediment. Accumulation of nitrogen and phosphorus on cropland occurs from decomposition of residual crop material, fertilization with chemical and manure fertilizers, atmospheric deposition, wildlife excreta and irrigation water. There are 4,794 cropland acres in the watershed, which account for approximately 35.9 percent of the watershed's area (MoRAP, 2005). The Versar study found only low concentrations of phosphorus and nitrogen and minor amounts of algae, whose growth is spurred by nutrients. The Department water quality study found non-detectable levels of Total Phosphorous in the Spring 2009 survey, but elevated levels in the Fall 2008 survey. Total Nitrogen levels were elevated in both seasons. These data, along with data reported by permittees, indicate that nutrients are a factor in the impairment of Hickory Creek.

According to the 2006-2007 Versar study, excessive siltation is a problem throughout the entire impaired segment of Hickory Creek. Sources of sediment are varied, originating from both severely eroding stream banks and agricultural fields throughout the watershed. Bottom substrates were primarily made up of fine particles such as silt, sand and/or clay.

Figure 2. Hickory Creek in Daviess County, Mo., with Sampling Sites and Permitted Facilities

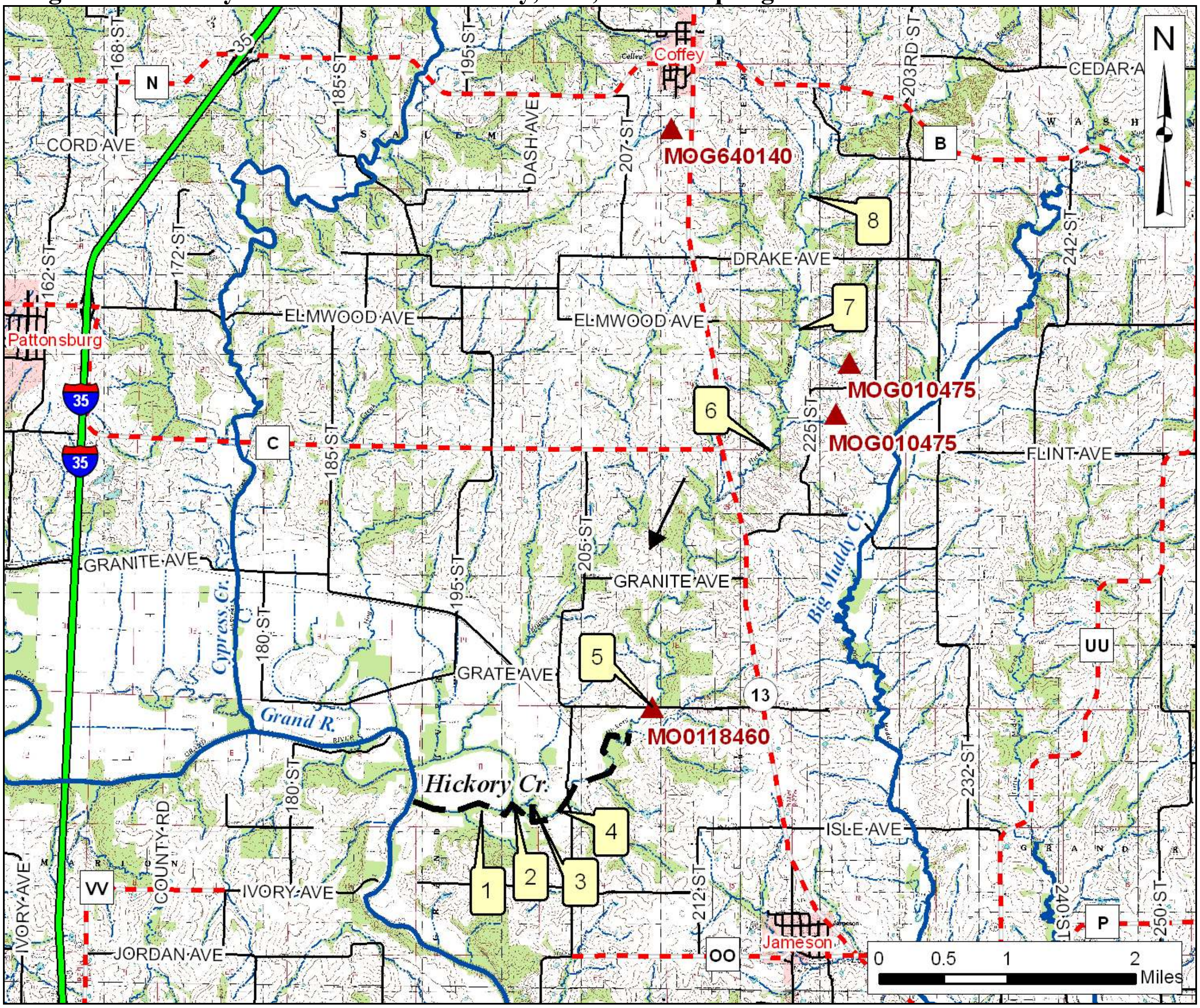


Table 5. Sample Site Index

Site Label	*Site Number*	*Site Description*
1	442/0.6	Hickory Cr near mouth
2		Hickory Cr MDNR bioassessment site 1, below 202 St.
3	442/1.2	Hickory Cr below 202 St
4		Hickory Cr MDNR bioassessment site 2, below 202 St.
5	442/1.5/0.3	Hickory Cr at Harbor Ave
6	442/1.5/3.9	Hickory Cr downstream of CG Hickory Cr (Site 15)
7	442/1.5/5.2	Hickory Cr at CG Hickory Cr (Site 3)
8	442/1.5/6.6	Hickory Cr downstream of CG Hickory Cr (Site 19)

Site number code: WBID/miles upstream of mouth/miles upstream of classified segment

Countywide data from the National Agricultural Statistics Service (USDA, 2009) were combined with the size of the Hickory Creek watershed to estimate there are 1,264 cattle in the watershed[4]. The cattle are most likely located on the approximately 5,191 acres of grassland in the watershed and runoff from these areas can be potential sources of nutrients, sediment from erosion, and other oxygen consuming substances. For example, animals grazing in pasture areas deposit manure directly upon the land surface and even though a pasture may be relatively large and animal densities low, the manure will often be concentrated near the feeding and watering areas in the field. These areas can quickly become barren of plant cover, increasing the possibility of erosion and contaminated runoff during a storm event. Based on Missouri's average recommended stocking rates of four acres per cow or 160 cows per square mile, the density of cattle in the Hickory Creek watershed (142-159 cattle per square mile) suggests they are not a potentially significant source of pollutants unless they are directly accessing the creek (Communication with Mark Kennedy, State Grazing Land Specialist, Texas County, Mo., 11/30/09).

The National Agricultural Statistics Service also reports there are 96,000 hogs and pigs in Daviess County and 45,000 hogs and pigs in Harrison County. Data was not available to estimate the number of these animals that might be located within the Hickory Creek watershed.

2.2.2 Runoff from Urban Areas

Storm water runoff from urban areas can also be a significant source of nutrients and other oxygen-consuming substances. Lawn fertilization can lead to high nutrient loads and pet wastes can contribute nutrients and other oxygen-consuming substances. For example, phosphorus loads from residential areas can be comparable to, or higher than, loading rates from agricultural areas (Reckhow et al., 1980; Athayde et al., 1983).

Storm water runoff from impervious surfaces such as parking lots and roofs is typically warmer than runoff from grassy and woodland areas. As this runoff is delivered to adjacent streams, it can lead to higher stream temperatures that lower the dissolved oxygen saturation capacity of the stream. Excessive discharge of suspended solids from urban areas (especially construction sites) can lead to streambed siltation problems and can convey nutrients and oxygen consuming substances to nearby streams. Leaking or illicitly connected sewers can also be a significant source of pollutant loads within urban areas.

Approximately 2.9 percent of the Hickory Creek watershed is classified as an urban area. This area includes county roads as well as part of the small town of Coffey (population 140) located at the edge of

[4] According to the National Agricultural Statistics Service, there were approximately 36,300 head of cattle in Daviess County in 2009 (www.nass.usda.gov/). According to the 2005 Missouri Resource Assessment Partnership land use and land cover data there are 228 square miles of grasslands in Daviess County. These two values result in a cattle density of approximately 159 cattle per square mile of grasslands. This density was then multiplied by the number of square miles of grassland in the Hickory Creek watershed (6.67) to estimate the number of cattle in the Daviess County part of the watershed (1,060). For Harrison County, the figures are 48,700 head of cattle in 342 square miles of grasslands which equates to 142 cattle per square mile of grassland. Multiplying that value by 1.44 square miles of grassland in the Harrison County portion of the watershed equals 204 cattle.

the watershed. Since the “urban” area is a small percent and the town is small, urban storm water runoff is not considered a significant contributor to the unknown impairment in Hickory Creek.

2.2.3 Onsite Wastewater Treatment Systems

Onsite wastewater treatment systems (e.g., individual home septic systems) that are properly designed and maintained should not serve as a source of contamination to surface waters; however, onsite wastewater treatment systems do fail for a variety of reasons. When these treatment systems fail hydraulically (surface breakouts) or hydrogeologically (inadequate soil filtration), there can be adverse effects to surface waters. Failing septic systems are sources of nutrients that can reach nearby streams through both surface runoff and ground water flows.

The exact number of onsite wastewater systems in the Hickory Creek Watershed is unknown. However, as discussed in Section 1.3 of this document, the estimated rural population of the Hickory Creek watershed is approximately 155 persons. Based on this population and an average density of 2.5 persons per household, there may be approximately 62 onsite wastewater treatment systems in the watershed. While there is no available information on the percent of systems failing within the Hickory Creek watershed, EPA reports that the statewide failure rate of onsite wastewater systems in Missouri is 30 to 50 percent (USEPA, 2002). Because they are a source of nutrients and oxygen-consuming substances, onsite wastewater treatment systems are considered a possible source of pollutants to Hickory Creek.

2.2.4 Riparian Habitat Conditions

Riparian[5] habitat conditions can also have a strong influence on the health of a stream. Wooded riparian buffers are a vital functional component of stream ecosystems and are instrumental in the detention, removal and assimilation of excess nutrients, soil and other pollutants before they reach the stream. Therefore, a stream with good riparian habitat is better able to prevent erosion and moderate the impacts of high nutrient loads than is a stream with poor habitat. Wooded riparian buffers can also provide shading that reduces stream temperatures, which can increase the dissolved oxygen saturation capacity of the stream.

The Versar study noted in 2006 that the riparian buffer was in fairly good condition, but land use just beyond the buffer was primarily row crops. During subsequent visits, the field crew noted that a large portion of the riparian forest was being harvested, with all the large trees being removed, including those that were adjacent to the stream banks. This activity will likely result in negative impacts to the stream as the stream’s banks will continue to destabilize. As the structural integrity of the stream’s banks are compromised, increased sediment inputs to the stream will exacerbate the problem of sediments smothering benthic habitat. The loss of trees will also allow for the summer sun to hit the stream more directly, causing an increase in temperature and a potential decrease in dissolved oxygen levels.

The riparian land use data and information found in Tables 6 and 7 were developed in 2005, before the tree removal noted in the above paragraph. As indicated in Table 6, however, almost 22 percent of the land in the Hickory Creek mainstem riparian corridor is classified as grassland, which might include pasture areas (MoRAP, 2005). Grassland provides limited riparian habitat compared to wooded areas,

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[5] A riparian corridor (or zone or area) is the linear strip of land running adjacent to a stream bank.

very little shading, and can also be associated with livestock activity. Another seven percent of the riparian corridor is classified as cropland, which also provides limited habitat and shading and can be associated with high nutrient loads and erosion related to runoff from agricultural areas. In general, a lack of good riparian habitat conditions should be considered as one component of water quality problems in Hickory Creek.

Table 6. Classified + Unclassified Hickory Creek Riparian Buffer (30 meters)

Land Use Type	Area - Acres	Area-Square Miles	Percentage
Urban	2	0.00	0.6
Row and Close-grown Crops	27	0.04	6.7
Grassland	87	0.14	21.8
Forest & Woodland	283	0.44	70.6
Open Water	2	0.00	0.4
Barren	0	0.00	0.0
Totals	**401**	**0.63**	**100.0**

Table 7. Classified Only Hickory Creek Riparian Buffer (30 meters)

Land Use Type	Area - Acres	Area-Square Miles	Percentage
Urban	0	0.00	0.0
Row and Close-grown Crops	5	0.01	7.8
Grassland	5	0.01	8.1
Forest & Woodland	54	0.08	82.4
Open Water	1	0.00	1.7
Barren	0	0.00	0.0
Totals	**66**	**0.10**	**100.0**

2.2.5 Other Stressors

The Versar study, as noted in Section 1, identified the causes of impairment in Hickory Creek as low dissolved oxygen levels, increased silt and sediment in the stream, poor habitat quality and low flow regime. Each cause is at least in part linked to the flow conditions in the channel. These stressors can mostly be linked to the nonpoint sources discussed above: Any or all of these four sources can cause or contribute to low dissolved oxygen.

- Any or all of the four sources mentioned above can cause or contribute to low dissolved oxygen.

- Runoff from both urban and rural or agricultural lands and the riparian zone can contribute silt and sediment. The number one pollutant entering Missouri's waters is sediment, with about 59 million tons of soil eroding from Missouri's land each year[6]. Sedimentation occurs when wind

[6] Missouri Soil and Water Districts Commission, March 2003, Needs Assessment, Plan To Address Identified Needs & A Summary To Date, add a date when link is checked http://www.dnr.mo.gov/env/swcp/2003%20needs%20assessment.pdf.

or water runoff carries soil particles from an area and transports them to a stream or lake. Excessive sedimentation clouds the water, which reduces the amount of sunlight reaching aquatic plants, covers fish spawning areas and food supplies, and clogs the gills of fish. In addition, other pollutants like nitrogen, phosphorus, pathogens, and heavy metals are often attached to soil particles and move into streams with the sediment (AgNPS 2010).

- Northern Missouri streams do not have the habitat quality that streams in other areas of Missouri have (e.g. Ozark streams) and typically have silty, muddy bottoms rather than gravel and cobble. Much of the habitat for macroinvertebrates in these streams relies on woody debris (fallen trees), rootwads and grass and herbaceous plant roots along the banks. However, while these structures may typically make up for the lack of gravel and cobble substrate, they are mostly absent in Hickory Creek. Benthic conditions such as these limit the range and abundance of benthic macroinvertebrates that can survive in Hickory Creek, making silt/sediment and habitat quality important factors in the stream's biological impairment. In addition, minimal or absent riparian forest (as noted in section 2.2.4) can also adversely impact habitat quality in the creek.

- The low flow regime: The Versar study noted that one of the major probable causes of impairment in Hickory Creek was the exceedingly low flow. During the fall of both 2006 and 2007, the upper reaches of the stream (about two miles of the impaired segment) were completely dry and did not satisfy the definition of a Class C stream found in rule. During these periods, flow in the stream ceased by permanent pools did not exist which supported aquatic life. This may partly be the result of a dry period and little water available for ground water recharge, with rainfall totals for summer and fall 2006 being the second lowest since 1998. Also, total yearly rainfall was the lowest since 1998 (Weather Underground, 2006). Data were obtained from Chillicothe, Mo., the closest available weather station to the stream and are presented in Appendix A. Low flow conditions affect nutrient yields, sediment loads and dissolved oxygen levels, all of which can put stress on aquatic communities. Low water levels also limit the amount of available habitat for aquatic communities by reducing the amount of available water. While the flow regime was no longer low in 2008-09, there is no way to accurately predict what the flow regime in Hickory Creek will be in the future.

3. Applicable Water Quality Standards and Numeric Water Quality Targets

Missouri's Water Quality Standards at 10 CSR 20-7.031 contains three main components: designated beneficial uses, water quality criteria that protect those uses (both numeric and narrative), and antidegradation requirements. These three components collectively ensure the quality of Missouri's waters is protected and maintained.

3.1 Designated Beneficial Uses

The designated beneficial uses for Hickory Creek (WBID 0442) are as follows:

- Livestock and Wildlife Watering
- Protection of Warm Water Aquatic Life
- Protection of Human Health (Fish Consumption)

Additional information regarding stream classifications and designated beneficial uses may be found at 10 CSR 20-7.031(1)(C) and Table H.

3.2 Impaired Use

The use that is impaired is the Protection of Warm Water Aquatic Life.

3.3 Antidegradation Policy

Missouri's Water Quality Standards include the EPA "three-tiered" approach to antidegradation, which can be found at 10 CSR 20-7.031(2):

Tier 1 – Protects existing uses and a level of water quality necessary to maintain and protect those uses. Tier I provides the absolute floor of water quality for all waters of the United States. Existing instream water uses are those uses that were attained on or after Nov. 28, 1975, the date of EPA's first Water Quality Standards Regulation.

Tier 2 – Protects and maintains the existing level of water quality where it is better than applicable water quality criteria. Before water quality in Tier 2 waters can be lowered, there must be an antidegradation review consisting of: (1) a finding that it is necessary to accommodate important economic and social development in the area where the waters are located; (2) full satisfaction of all intergovernmental coordination and public participation provisions; and (3) assurance that the highest statutory and regulatory requirements for point sources and best management practices for nonpoint sources are achieved. Furthermore, water quality may not be lowered to less than the level necessary to fully protect the "fishable/swimmable" uses and other existing uses.

Tier 3 – Protects the quality of outstanding national and state resource waters, such as waters of national and state parks, wildlife refuges and waters of exceptional recreational or ecological significance. There may be no new or increased discharges to these waters and no new or increased discharges to tributaries of these waters that would result in lower water quality.

3.4 Specific Criteria

Because Hickory Creek has been listed as impaired for unknown pollutants, no identifiable numeric criteria apply. However, all Missouri Streams are protected by the general criteria contained in Missouri's Water Quality Standards at 10 CSR 20-7.31(3). The particular criteria that apply to Hickory Creek state:

(A) Waters shall be free from substances in sufficient amounts to cause the formation of putrescent, unsightly, or harmful bottom deposits or prevent full maintenance of beneficial uses.

(C) Waters shall be free from substances in sufficient amounts to cause unsightly color or turbidity, offensive odor, or prevent full maintenance of beneficial uses.

(D) Waters shall be free from substances or conditions in sufficient amounts to result in toxicity to human, animal, or aquatic life.

(G) Waters shall be free from physical, chemical, or hydrologic changes that would impair the natural biological community.

3.5. Water Quality Targets

The cause of impairment to the aquatic community in Hickory Creek is unknown. The Versar water quality report identified low dissolved oxygen levels, increased silt and sediment in the stream, poor habitat quality and low flow regime as the stressors. The Department water quality study, conducted during wetter years, showed a healthy aquatic community and acceptable levels of dissolved oxygen. Hydrologic records are not available from which to determine what is a "normal" flow regime for this stream, nor what are all the factors affecting flow in Hickory Creek. Because TMDLs are not written to address habitat issues, the Hickory Creek TMDL must target water quality conditions that attain the protection of warm water aquatic life designated use. Load capacities must be developed to reduce those pollutants causing or contributing to the unknown impairment. Therefore, given the information derived from the Department and Versar water quality studies, this Hickory Creek TMDL will address sediment and nutrients. It should be noted that while Missouri does not yet have numeric criteria for nutrients in its Water Quality Standards, the department is in the process of developing criteria for these pollutants. During the interim, peer reviewed and approved ecoregion total nitrogen and total phosphorous values are available from which to set targets applicable to the ecoregion in which Tributary to Hickory Creek resides. Targeting sediment will ensure already limited in-stream habitat is protected from additional sedimentation, and targeting nutrients will ensure these pollutants do not cause or contribute to a dissolved oxygen impairment or conditions that would lead to a violation of the narrative criteria.

There are many quantitative indicators of sediment, such as total suspended solids (TSS), turbidity, and bedload sediment, which are appropriate to describe sediment in rivers and streams. TSS was selected as the numeric target for sediment in the TMDL because it enables the use of the available data, including permit conditions and monitoring data. To address nutrients, both total nitrogen and total phosphorus are selected because both nutrients are generally elevated by point and nonpoint sources.

4 Load Capacity

Load capacity is defined as the maximum pollutant load that a water body can assimilate and still attain water quality standards. This load is then divided among the point source (wasteload allocation, or WLA) and nonpoint source (load allocation or LA) contributions to the stream, with an allowance for an explicit margin of safety, or MOS. If the margin of safety is implicit, no numeric allowance is necessary. Load capacity can be expressed as the following equation:

$$\text{Load capacity} = \sum \text{WLA} + \sum \text{LA} + \text{MOS}$$

The wasteload allocation and load allocation are calculated by multiplying the appropriate flow in cubic feet per second, or cfs, by the appropriate pollutant concentration in mg/L. A conversion factor of 5.395 is used to convert the units (cfs and mg/L) to pounds per day (lbs/day).

(stream flow in cfs)(maximum allowable pollutant concentration in mg/L)(5.395)= load in lbs/day

Critical conditions must be considered when the load capacity is calculated. Without a known pollutant, the critical period is difficult to determine. Given that the stream was dry in the fall of both years, low flow periods could be considered the critical conditions. In this TMDL, load duration curves, or LDCs, have been created. These models cover all flow conditions, so a target and load can be determined for any and all flows.

4.1 Modeling for Total Suspended Solids and Nutrients

Dissolved oxygen concentrations in streams are determined by factors such as photosynthetic productivity, respiration (autotrophic and heterotrophic), reaeration and temperature. These factors are influenced by natural and anthropogenic conditions within a watershed. Generally, reaeration is based on the physical properties of the stream and on the capacity of water to hold dissolved oxygen. This capacity is mainly determined by water temperature with colder water having a higher saturation concentration for dissolved oxygen than warmer water. In a review of variables and their importance in dissolved oxygen modeling, Nijboer and Verdonschot (2004) categorized the impact of a number of variables on oxygen depletion. For this TMDL, the effects of temperature and the physical aspects of the stream itself were discounted. Even though the hydrological regime of historic prairie streams was modified by changes in land cover and channelization, manipulation of these parameters does not address a pollutant and so is not the goal of a TMDL. Pollutants which result in oxygen concentrations below saturation are:

- fine particle size of bottom sediment
- high nutrient levels (phosphorus and nitrogen)
- suspended particles of organic matter

Because these three pollutants vary to a large extent based on anthropogenic influences, they are appropriate targets for a TMDL written to address an impairment where the pollutant is unknown.

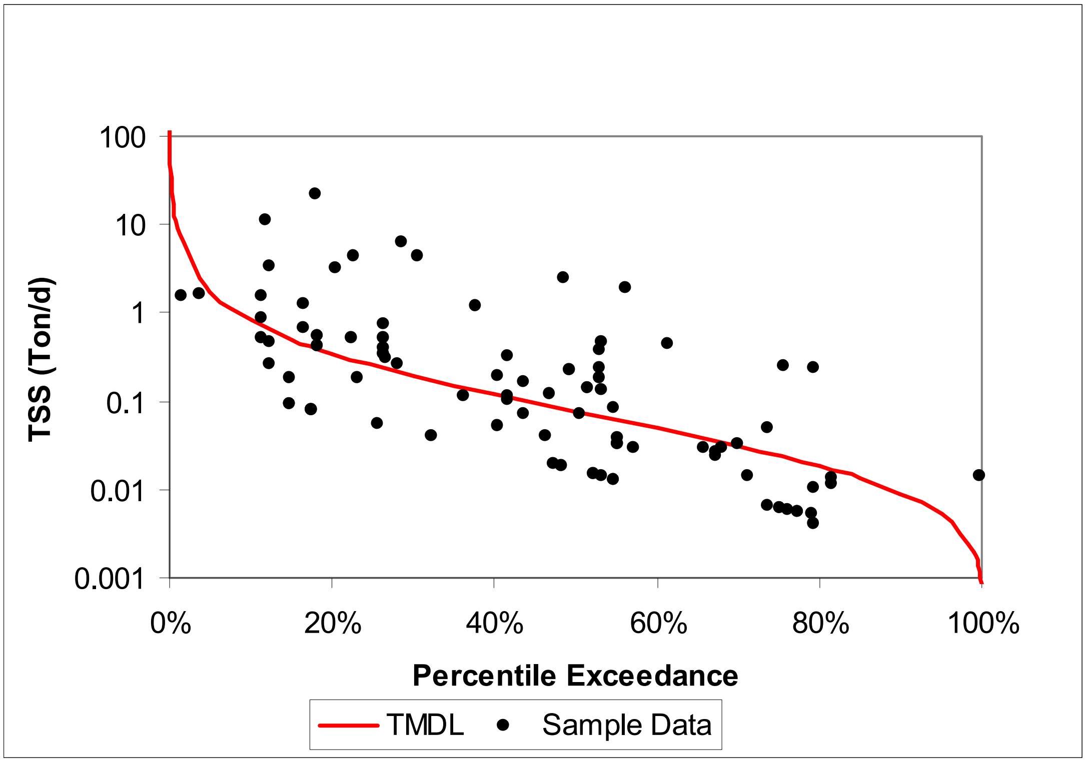
4.1.1 Total Suspended Solids

Since fine particle sized sediment and suspended particles of organic matter are derived from similar loading conditions of terrestrial and stream bank erosion, this TMDL will have total suspended solids (sediment) as one of its allocations. This target was derived based on a reference approach by targeting the 25th percentile baseload concentration (10 mg/L) of total suspended solids measurements[7] in the geographic region where Hickory Creek is located (see Appendix C for a list of sites and data)[8]. For a full description of the development of total suspended solids targets using reference LDCs refer to Appendix B.

The load capacity for total suspended solids has been defined as a curve (LDC) over the range of flows for Hickory Creek, from high flows on the left to low flows on the right. Figure 3 shows the LDC for the total suspended solids, or TSS, TMDL for Hickory Creek (curve) as well as individual sample results (points) for this pollutant. Figure 3 is populated with data gathered by the Department and various permitted facilities in the watershed (See Appendix A.2).

[7] From U.S. Geological Survey non-filterable residue data, the 25th percentile of the data equals 10 mg/L.
[8] The EPA ecoregion for Hickory Creek is Level III 40, the Central Irregular Plains

Figure 3. TMDL Load Duration Curve for Total Suspended Solids in Hickory Creek



4.1.2 Nutrients

To address nutrient levels in Hickory Creek, the TMDL targeted EPA nutrient ecoregion reference concentrations for the Central Irregular Plains (Level III 40). These concentrations are 0.855 mg/L total nitrogen[9] and 0.092 mg/L total phosphorus (USEPA 2001a and USEPA 2001b).

To develop load duration curves for total nitrogen and total phosphorus, a method similar to that used for total suspended solids was employed (Appendix C). First, total nitrogen and total phosphorus measurements were collected from U.S. Geological Survey, or USGS, sites in the vicinity of the impaired stream (See Tables C.2 and C.3 in Appendix C). These data were adjusted such that the median of the measured data was equal to the ecoregion reference concentration. This was accomplished by subtracting the difference of the data median and the reference concentration. Where the result was a negative concentration, the data point in question was replaced with the minimum concentration seen in the measured data. This resulted in a modeled data set which retained much of the original variability seen in the measured data. These modeled data were then regressed as instantaneous load versus flow. The resultant regression equation was used to create the load duration curves in Figures 4 and 5.

[9]Total Nitrogen is the sum of Total Kjeldahl nitrogen, ammonia as nitrogen, and nitrate plus nitrite as nitrogen.

Figure 4. TMDL Load Duration Curve for Total Phosphorus in Hickory Creek

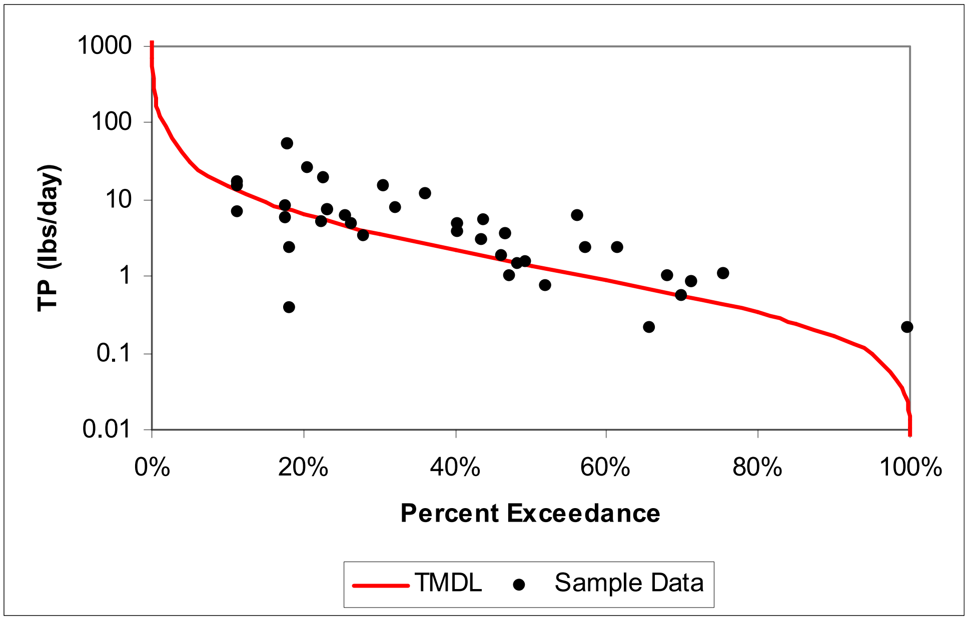
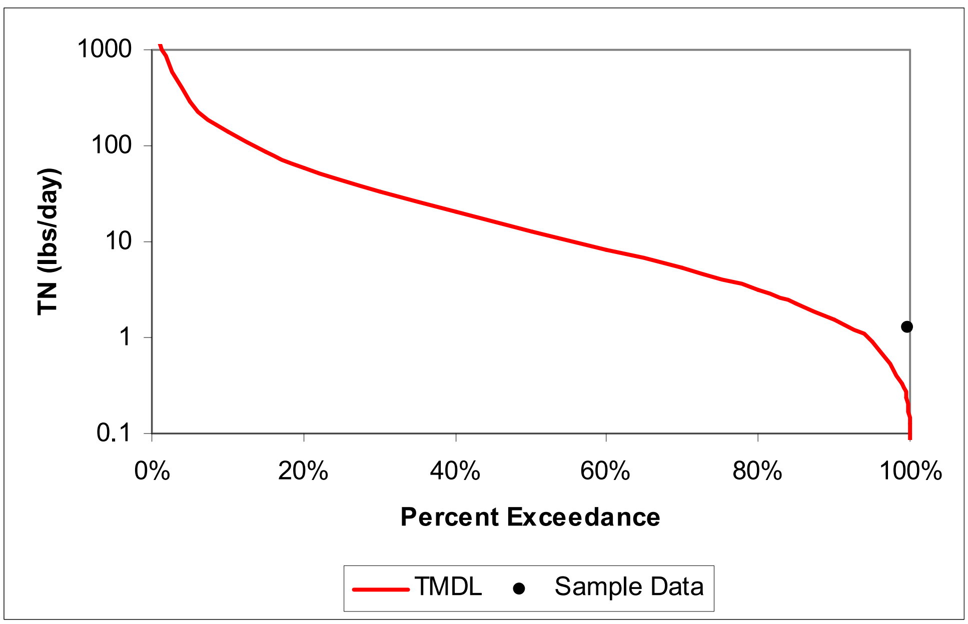


Figure 5. TMDL Load Duration Curve for Total Nitrogen in Hickory Creek



5 Wasteload Allocation

The wasteload allocation is the portion of the load capacity that is allocated to existing or future point sources of pollution. No point source had been determined to contribute to the impairment in Hickory Creek. The permitted facilities in the watershed discharge an insignificant volume of effluent and are unlikely to discharge during the targeted critical, low flow conditions. Therefore, wasteload allocations for permitted facilities within the watershed will remain equal to existing permit limits.

6 Load Allocation

The load allocation includes all existing and future nonpoint sources and natural background contributions (40 CFR § 130.2(g)). The load allocations for the Hickory Creek TMDL are for all nonpoint sources of total suspended solids (TSS), total nitrogen (TN), and total phosphorous (TP) and include loads from agricultural lands, runoff from urban areas, livestock, and failing onsite wastewater treatment systems. The load allocations in Table 8 are based on the load duration curves found in Figures 3, 4 and 5.

Table 8. Load Allocations for Hickory Creek – TN, TP and TSS

Percentile flow exceedance	Flow (cfs)	TN TMDL (lbs/d)	TN LA (lbs/d)	TN sum WLA (lbs/d)	TP TMDL (lbs/d)	TP LA (lbs/d)	TP sum WLA (lbs/d)	TSS TMDL (T/d)	TSS LA (T/d)	TSS sum WLA (T/d)
95%	0.19	0.89	0.89	0.00	0.10	0.10	0.00	0.01	0.01	0.000
90%	0.34	1.56	1.56	0.00	0.17	0.17	0.00	0.01	0.01	0.000
70%	1.15	5.30	5.30	0.00	0.57	0.57	0.00	0.03	0.03	0.000
50%	2.81	12.95	12.95	0.00	1.39	1.39	0.00	0.08	0.08	0.000
30%	7.16	33.02	33.02	0.00	3.55	3.55	0.00	0.19	0.19	0.000
10%	30.09	138.81	138.81	0.00	14.94	14.94	0.00	0.81	0.81	0.000
5%	62.17	286.75	286.75	0.00	30.86	30.86	0.00	1.68	1.68	0.000

Note: TSS is in tons per day (t/d); *The MOS is implicit. See Section 7

7 Margin of Safety

A margin of safety is required in the TMDL calculation to account for uncertainties in scientific and technical understanding of water quality in natural systems. The margin of safety is intended to account for such uncertainties in a conservative manner. Based on EPA guidance, the margin of safety can be achieved through one of two approaches:

(1) Explicit - Reserve a portion of the load capacity as a separate term in the TMDL.

(2) Implicit - Incorporate the margin of safety as part of the critical conditions for the wasteload allocation and the load allocation calculations by making conservative assumptions in the analysis.

The margin of safety for the Hickory Creek TMDL is implicit and based on the conservative assumptions used in developing and applying the TMDL load duration curves.

8 Seasonal Variation

Federal regulations at 40 CFR §130.7(c)(1) require that TMDLs take into consideration seasonal variation in applicable standards. The Hickory Creek TMDL takes seasonal variation into account through the use of load duration curves. Load duration curves represent the allowable pollutant load under different flow conditions and across all seasons. The results obtained using the load duration curve method are more robust and reliable over all flows and seasons when compared with those obtained under critical low-flow conditions.

9 Monitoring Plans

The Department has not yet scheduled post-TMDL monitoring for Hickory Creek. The Department will, however, continue to routinely examine physical habitat, water quality, invertebrate community, and fish community data collected by other state and federal agencies. One example is the Resource Assessment and Monitoring Program administered by the Missouri Department of Conservation. This program randomly samples streams across Missouri on a five to six year rotating schedule.

10 Implementation

No implementation plan has been identified for Hickory Creek. While biological indices calculated following the 2008 – 2009 study by the Department indicate no impairment to the aquatic community, TMDL LDCs show that improvement can be made to levels of total suspended solids, total nitrogen and total phosphorus reaching the stream. The Versar study points out that erosion control plans for surrounding farmland could be created and implemented to reduce sediment loads reaching the stream. Efforts could also be made to maintain the forested buffers that protect Hickory Creek from runoff from nearby farm fields. In addition, where nutrient management plans are not already being implemented in the watershed, it would be beneficial to initiate them. While the Versar study also recommends investigating the cause of the low flow conditions, the Department study suggests that those conditions were caused naturally by drought. Comparing the Department and Versar biological studies suggests that increased flows contributed to an improved aquatic community and elevated dissolved oxygen levels. However, it is unknown if these wetter conditions will continue to persist.

11 Reasonable Assurance

The Department has the authority to issue and enforce Missouri State Operating Permits. For TMDLs that address point sources of pollution, effluent limits determined from TMDL wasteload allocations incorporated into a state permit, along with effluent monitoring reported to the Department, should provide a reasonable assurance that instream water quality standards will be met. In the case of Hickory Creek, however, there are no point source contributions to the impairment as found in Section 2.1.

In most cases, "Reasonable Assurance" in reference to TMDLs relates only to point sources. As a result, any assurances that nonpoint sources of possible pollutants contributing to a degraded aquatic community will implement measures to reduce their contribution in the future will not be found in this section. Instead, discussion of reduction efforts relating to nonpoint sources can be found in the "Implementation" section of this TMDL.

12 Public Participation

This water quality limited segment of Hickory Creek is included on the approved 2008 303(d) List of impaired waters for Missouri. The public notice period for the draft Hickory Creek TMDL was April 13 to May 28, 2010. Groups that received the public notice announcement included the Missouri Clean

Water Commission, the Water Quality Coordinating Committee, Missouri Department of Conservation, Daviess County Commissioners, Harrison County Presiding Commissioner, Daviess County Soil and Water Conservation District, 11 local Stream Team volunteers and the two state legislators representing Daviess and Harrison counties. Also, the public notice, the Hickory Creek TMDL Information Sheet and this document were posted on the Department website, making them available to anyone with access to the Internet. No comments were received regarding this TMDL.

13 Administrative Record and Documentation

An administrative record on the Hickory Creek TMDL has been assembled and is being kept on file with the department. It includes the following:

Stressor Identification for Willow Branch, Long Branch, Hickory Creek & Indian Creek, Missouri. [2006-2007] May 2008. Versar, Inc., 9200 Rumsey Rd, Columbia, MD 21045. Prepared for U.S. EPA, Region 7, Kansas City, MO

Biological Assessment Report, Hickory Creek, Daviss County, Missouri, Sept. 2008 - March 2009, Department of Natural Resources, Environmental Services Program

Models and calculations for Load Duration Curves

Missouri State Operating Permits #MO-0118460, MO-G010475 and MO-G640140

All documents pertaining to the Public Notice (Information Sheet, PN announcement, StreamGram, press release, mailing lists, etc)

14 Appendices

Appendix A – Weather Statistics and Water Quality Data

Appendix B – Development of Suspended Sediment Targets using Reference Load Duration Curves

Appendix C – Development of Nutrient Targets using EPA Recommended Ecoregion Nutrient Criteria with Load Duration Curves

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USEPA (U.S. Environmental Protection Agency). 2000. Ambient Water Quality Criteria Recommendations Information Supporting the Development of State and Tribal Nutrient Criteria Rivers and Streams in Nutrient Ecoregion IX, EPA 822-B-00-019, 91p.

_______2001a. Ambient Water Quality Criteria Recommendations: Rivers and Streams in Nutrient Ecoregion IX. U.S. Environmental Protection Agency, Washington DC. EPA 822-B-001-019.

_______2001b. Ambient Water Quality Criteria Recommendations: Rivers and Streams in Nutrient Ecoregion X. U.S. Environmental Protection Agency, Washington DC. EPA 822-B-001-016.

________2002. Onsite Wastewater Treatment System Manual. EPA/625/R-00/008. U.S. Environmental Protection Agency, Office of Water, Washington, DC, and Office of Research and Development, Cincinnati, OH. February 2002

Appendix A

A.1. Weather statistics for Chillicothe, Missouri, June,1998 - October, 2007. All data from the National Weather Service (NWS).

Note: No data available for 2000.

Month/Year	Precipitation (Inches)	Average Maximum Temperature ^oF	Average Minimum Temperature ^oF	Average Mean Temperature ^oF
Jun-1998	8.09	80	61	71
Jul-1998	5.74	85	68	76
Aug-1998	5.14	85	66	76
Sep-1998	7.45	82	60	71
Oct-1998	8.01	66	46	56
Nov-1998	4.22	55	36	46
Dec-1998	1.21	42	23	33
Jan-1999	1.17	32	17	25
Feb-1999	1.64	48	31	39
Mar-1999	2.19	51	31	41
Apr-1999	6.37	64	44	55
May-1999	5.91	72	51	62
Jun-1999	5.63	80	62	71
Jul-1999	2.28	89	68	79
Aug-1999	2.21	84	63	73
Sep-1999	4.56	77	49	63
Oct-1999	0.26	68	41	55
Nov-1999	1.45	62	37	50
Dec-1999	1.82	42	23	33
Jan-2001	2.09	35	18	27
Feb-2001	4.17	36	20	28
Mar-2001	2.90	46	27	37
Apr-2001	4.01	71	47	59
May-2001	9.38	73	55	64
Jun-2001	6.89	81	62	71
Jul-2001	2.16	87	70	79
Aug-2001	4.18	86	65	75
Sep-2001	3.27	75	53	64
Oct-2001	3.23	65	42	54
Nov-2001	0.68	61	39	50
Dec-2001	0.78	46	26	36
Jan-2002	1.84	43	22	33
Feb-2002	1.54	44	24	34
Mar-2002	0.81	51	27	39
Apr-2002	4.02	66	43	54
May-2002	6.80	71	49	60
Jun-2002	2.76	85	64	75
Jul-2002	2.73	90	67	79
Aug-2002	5.85	85	64	75
Sep-2002	0.62	83	56	69

Month/Year	Precipitation (Inches)	Average Maximum Temperature ^oF	Average Minimum Temperature ^oF	Average Mean Temperature ^oF
Oct-2002	2.84	60	39	50
Nov-2002	0.29	50	29	39
Dec-2002	0.01	45	23	34
Jan-2003	0.28	35	14	25
Feb-2003	0.55	38	17	28
Mar-2003	0.88	53	29	41
Apr-2003	5.21	66	44	55
May-2003	2.97	73	51	62
Jun-2003	4.96	80	58	69
Jul-2003	4.13	90	66	78
Aug-2003	4.83	91	66	78
Sep-2003	4.29	75	50	63
Oct-2003	1.59	69	43	56
Nov-2003	1.88	51	32	42
Dec-2003	2.64	41	27	34
Jan-2004	0.41	33	16	25
Feb-2004	0.41	39	20	30
Mar-2004	5.39	54	36	45
Apr-2004	2.38	66	43	55
May-2004	5.06	76	56	66
Jun-2004	3.80	79	59	69
Jul-2004	5.38	83	64	73
Aug-2004	7.21	79	60	69
Sep-2004	3.00	80	55	67
Oct-2004	5.22	65	46	56
Nov-2004	2.06	52	37	45
Dec-2004	0.57	42	23	33
Jan-2005	2.37	34	21	28
Feb-2005	2.61	46	27	37
Mar-2005	1.42	53	30	42
Apr-2005	1.28	67	44	56
May-2005	2.23	75	50	63
Jun-2005	7.39	85	64	74
Jul-2005	0.93	90	65	77
Aug-2005	4.02	88	65	76
Sep-2005	1.86	82	58	70
Oct-2005	3.55	67	44	55
Nov-2005	1.55	55	33	44
Dec-2005	1.49	35	21	28
Jan-2006	2.20	47	30	38
Feb-2006	0.09	43	20	31
Mar-2006	4.49	53	34	44
Apr-2006	3.40	71	46	59
May-2006	1.29	74	52	64
Jun-2006	2.10	86	61	73
Jul-2006	2.89	91	68	79

Month/Year	Precipitation (Inches)	Average Maximum Temperature ^oF	Average Minimum Temperature ^oF	Average Mean Temperature ^oF
Aug-2006	6.07	87	66	77
Sep-2006	1.40	75	52	63
Oct-2006	2.97	63	41	52
Nov-2006	1.57	55	34	45
Dec-2006	1.99	43	26	35
Jan-2007	0.98	35	19	27
Feb-2007	2.61	31	15	23
Mar-2007	4.69	58	37	48
Apr-2007	3.60	60	37	49
May-2007	5.07	76	55	65
Jun-2007	3.79	80	60	71
Jul-2007	0.84	85	63	74
Aug-2007	4.32	88	68	77
Sep-2007	0.86	80	54	67
Oct-2007	4.49	68	47	58

A.2. Data used in Populating Load Duration Curves.

All units in milligrams per liter, or mg/L, unless otherwise noted (see notes at end of table)

Org	Site	Site Name	Year	Mo	Day	Flow	C	DO	pH	SC	NH3N	TKN	NO3N	TN	PO4	TP	TSS
ContiGroup	442/1.5/5.2	Hickory Cr. @ CG Hickory Cr. (Site 3)	2001	1	17	0.95	0		7.6		0.99		4.8				7
ContiGroup	442/1.5/3.9	Hickory Cr. DS of CG Hickory Cr. (Site 15)	2001	1	17	2.09	0		7.6		0.99		4.8				7.8
ContiGroup	442/1.5/5.2	Hickory Cr. @ CG Hickory Cr. (Site 3)	2001	2	7	9.22	0		7.8		0.99		2				54
ContiGroup	442/1.5/3.9	Hickory Cr. DS of CG Hickory Cr. (Site 15)	2001	2	7	1.67	0		7.7		0.99		2				26
ContiGroup	442/1.5/6.6	Hickory Cr. DS of CG Hickory Cr. (Site 19)	2001	2	7	15.7	0		7.6		0.99		2.1				33
ContiGroup	442/1.5/3.9	Hickory Cr. DS of CG Hickory Cr. (Site 15)	2001	3	27	0.56	2		7.3		0.99		1.2				78
ContiGroup	442/1.5/5.2	Hickory Cr. @ CG Hickory Cr. (Site 3)	2001	4	25	37.6	20		7.9		0.99		0.05				25
ContiGroup	442/1.5/3.9	Hickory Cr. DS of CG Hickory Cr. (Site 15)	2001	4	25	7.16	21		7.7		0.99		0.04				9
ContiGroup	442/1.5/6.6	Hickory Cr. DS of CG Hickory Cr. (Site 19)	2001	4	25	0.31	21		7.7		0.99		0.05				8
ContiGroup	442/1.5/5.2	Hickory Cr. @ CG Hickory Cr. (Site 3)	2001	5	16			7.7									18
ContiGroup	442/1.5/3.9	Hickory Cr. DS of CG Hickory Cr. (Site 15)	2001	5	16			5.7									18
ContiGroup	442/1.5/3.9	Hickory Cr. DS of CG Hickory Cr. (Site 15)	2001	5	29	1.26	18		7.4		0.99		0.32				9
ContiGroup	442/1.5/5.2	Hickory Cr. @ CG Hickory Cr. (Site 3)	2001	6	26	3.66	22		7.6		0.99		0.63				16
ContiGroup	442/1.5/3.9	Hickory Cr. DS of CG Hickory Cr. (Site 15)	2001	6	26	12.5	22		7.5		0.99		0.67				29
ContiGroup	442/1.5/5.2	Hickory Cr. @ CG Hickory Cr. (Site 3)	2001	7	24	0.71	28		7.4		0.99		0.05				2.499
ContiGroup	442/1.5/3.9	Hickory Cr. DS of CG Hickory Cr. (Site 15)	2001	7	24	0.84	27		7.7		0.99		0.33				2.499
ContiGroup	442/1.5/5.2	Hickory Cr. @ CG Hickory Cr. (Site 3)	2001	8	27	4.29	23		7.2		0.99		0.23				2.499
ContiGroup	442/1.5/3.9	Hickory Cr. DS of CG	2001	8	27	0.74	23		7.3		0.99		0.2				2.499

Org	Site	Site Name	Year	Mo	Day	Flow	C	DO	pH	SC	NH3N	TKN	NO3N	TN	PO4	TP	TSS
		Hickory Cr. (Site 15)															
ContiGroup	442/1.5/5.2	Hickory Cr. @ CG Hickory Cr. (Site 3)	2001	9	26	0.34	15		6.8		0.99		0.07				19
ContiGroup	442/1.5/3.9	Hickory Cr. DS of CG Hickory Cr. (Site 15)	2001	9	26	0.23	15		6.7		0.99		0.06				2.499
ContiGroup	442/1.5/3.9	Hickory Cr. DS of CG Hickory Cr. (Site 15)	2001	10	30	0.42	16		7.7		0.99		0.015				2.499
ContiGroup	442/1.5/5.2	Hickory Cr. @ CG Hickory Cr. (Site 3)	2001	11	28	2.25	10		7.3		0.99		0.015				7
ContiGroup	442/1.5/3.9	Hickory Cr. DS of CG Hickory Cr. (Site 15)	2001	11	28	1.01	9		7.2		0.99		0.015				6
ContiGroup	442/1.5/3.9	Hickory Cr. DS of CG Hickory Cr. (Site 15)	2001	12	11	0.25	5		8.2		0.99		0.015				2.499
ContiGroup	442/1.5/3.9	Hickory Cr. DS of CG Hickory Cr. (Site 15)	2002	1	22		10		7.2		0.12		0.099		0.099		5
ContiGroup	442/1.5/5.2	Hickory Cr. @ CG Hickory Cr. (Site 3)	2002	1	22		9		7		0.0499		0.099		0.05		1.99
ContiGroup	442/1.5/6.6	Hickory Cr. DS of CG Hickory Cr. (Site 19)	2002	1	22		9		7.3		0.0499		0.099		0.05		114
ContiGroup	442/1.5/3.9	Hickory Cr. DS of CG Hickory Cr. (Site 15)	2002	2	20	2.42	5		7.4		0.0499		0.2		0.2		5
ContiGroup	442/1.5/5.2	Hickory Cr. @ CG Hickory Cr. (Site 3)	2002	2	20	2.15	5		7.1		0.0499		0.2		1.95		5
ContiGroup	442/1.5/6.6	Hickory Cr. DS of CG Hickory Cr. (Site 19)	2002	2	20	2.31	5		7.1		0.0499		0.3		2.19		6
ContiGroup	442/1.5/3.9	Hickory Cr. DS of CG Hickory Cr. (Site 15)	2002	3	18	0.65	9		7.9		0.0499		0.099		0.02499		1.99
ContiGroup	442/1.5/5.2	Hickory Cr. @ CG Hickory Cr. (Site 3)	2002	3	18	1.08	9		7.6		0.0499		0.099		0.099		13
ContiGroup	442/1.5/6.6	Hickory Cr. DS of CG Hickory Cr. (Site 19)	2002	3	18	1.08	10		7.6		0.0499		0.099		0.02499		1.99
ContiGroup	442/1.5/5.2	Hickory Cr. @ CG Hickory Cr. (Site 3)	2002	4	23	2.82	13		8.2		0.0499		0.7		0.06		28
ContiGroup	442/1.5/5.2	Hickory Cr. @ CG Hickory Cr. (Site 3)	2002	5	31	1.12	20		7.5		0.0499		0.2		0.07		5
ContiGroup	442/1.5/5.2	Hickory Cr. @ CG Hickory Cr. (Site 3)	2002	6	26	0.16	30		7.3		0.0499		0.099		0.69		19
ContiGroup	442/1.5/3.9	Hickory Cr. DS of CG	2002	4	23	3.85	14		8.3		0.0499		0.7		0.07		15

Org	Site	Site Name	Year	Mo	Day	Flow	C	DO	pH	SC	NH3N	TKN	NO3N	TN	PO4	TP	TSS
		Hickory Cr. (Site 15)															
ContiGroup	442/1.5/3.9	Hickory Cr. DS of CG Hickory Cr. (Site 15)	2002	5	31	0.72	21		7.4		0.0499		0.4		0.06		9
ContiGroup	442/1.5/3.9	Hickory Cr. DS of CG Hickory Cr. (Site 15)	2002	6	26	0.77	30		7.4		0.0499		0.099		0.15		66
ContiGroup	442/1.5/6.6	Hickory Cr. DS of CG Hickory Cr. (Site 19)	2002	4	23	5	15		7.9		0.0499		0.6		0.06		13
ContiGroup	442/1.5/6.6	Hickory Cr. DS of CG Hickory Cr. (Site 19)	2002	5	31	0.01	14		7.1		0.12		0.099		0.02499		65
ContiGroup	442/1.5/6.6	Hickory Cr. DS of CG Hickory Cr. (Site 19)	2002	6	26	0.14	30		7.3		0.0499		0.099		0.54		1.99
ContiGroup	442/1.5/5.2	Hickory Cr. @ CG Hickory Cr. (Site 3)	2002	5	21			17									4
ContiGroup	442/1.5/3.9	Hickory Cr. DS of CG Hickory Cr. (Site 15)	2002	5	21			15.1									1.99
ContiGroup	442/1.5/6.6	Hickory Cr. DS of CG Hickory Cr. (Site 19)	2002	5	21			16.4									1.99
ContiGroup	442/1.5/5.2	Hickory Cr. @ CG Hickory Cr. (Site 3)	2002	7	24		28		7.4		0.12		0.099			0.0299	8
PSF	442/1.5/0.3	Hickory Cr. @ Harbor Ave.	2004	4	28	0.6	14	7.1	7.7		0.0499		0.099			0.07	1.99
PSF	442/1.5/0.3	Hickory Cr. @ Harbor Ave.	2004	5	26	21	16	11.7	7.8		0.0499		1.6			0.31	135
PSF	442/1.5/0.3	Hickory Cr. @ Harbor Ave.	2004	6	23	5.5	17.3	6.2	8.4		0.0499		0.6			0.11	1.99
PSF	442/1.5/0.3	Hickory Cr. @ Harbor Ave.	2004	7	29	0.5	19.7	6.5	7.8		0.0499		0.3			0.07	11
PSF	442/1.5/0.3	Hickory Cr. @ Harbor Ave.	2004	8	26	45	21.9	8.4	8.5		0.0499		0.4			0.34	205
PSF	442/1.5/0.3	Hickory Cr. @ Harbor Ave.	2004	9	22	1.1	20	7.9	7.7		0.0499		0.099			0.09	11
PSF	442/1.5/0.3	Hickory Cr. @ Harbor Ave.	2004	10	28	0.45	15	8.2	7.8		0.0499		0.099			0.19	1.99
PSF	442/1.5/0.3	Hickory Cr. @ Harbor Ave.	2005	1	26	1	2		7.3		0.13		1.8			0.38	92
PSF	442/1.5/0.3	Hickory Cr. @ Harbor Ave.	2005	2	25	3.5	2		8.1		0.0499		0.8			0.06	9
PSF	442/1.5/0.3	Hickory Cr. @ Harbor	2005	3	21	1.5	8		8.2		0.0499		0.099			0.05	1.99

Org	Site	Site Name	Year	Mo	Day	Flow	C	DO	pH	SC	NH3N	TKN	NO3N	TN	PO4	TP	TSS
		Ave.															
PSF	442/1.5/0.3	Hickory Cr. @ Harbor Ave.	2005	4	27	3	9	15.5	8		0.0499		1.4			0.09	26
PSF	442/1.5/0.3	Hickory Cr. @ Harbor Ave.	2005	5	23	1.2	17	8.6	8.1		0.0499		0.4			0.08	1.99
PSF	442/1.5/0.3	Hickory Cr. @ Harbor Ave.	2005	6	20	1	19	5.4	8.1		0.0499		0.5			0.08	16
Versar	442/0.6	Hickory Cr near mouth	2006	10	16	0	8.8	3	7.4	496							
Versar	442/0.6	Hickory Cr near mouth	2006	10	17						0.0099	0.8	0.3	1.1	0.02	0.18	24
Versar	442/1.2	Hickory Cr. bl. 202 St.	2007	3	27	0.02	18	9.2	8.3		0.099	0.2499	0.24	0.24	0.06	0.14	14
Versar	442/0.6	Hickory Cr near mouth	2007	3	27	0.04	19	8.5	7.4	532	0.099	0.2499	0.11	0.11	0.07	0.18	4
PSF	442/1.5/0.3	Hickory Cr. @ Harbor Ave.	2007	3	28	1.6	18		8.7		0.0499		0.099			0.13	6
PSF	442/1.5/0.3	Hickory Cr. @ Harbor Ave.	2007	4	24	0.4	14.3	13	7.8		0.0499		0.099			0.12	6
PSF	442/1.5/0.3	Hickory Cr. @ Harbor Ave.	2007	5	23	0.9	18.6	5.6	7.9		0.0499		0.099			0.09	20
PSF	442/1.5/0.3	Hickory Cr. @ Harbor Ave.	2007	6	27	0.03	23.6	7.6	7.4		0.17		0.099			0.18	12
PSF	442/1.5/0.3	Hickory Cr. @ Harbor Ave.	2007	7	24	0.08	21.8	4.5	7.7		0.0499		0.099			0.36	7
Versar	442/0.6	Hickory Cr near mouth	2007	9	16	0	13	6.6	7.1	359	0.0099	0.2499	0.099		0.02	0.15	5
PSF	442/1.5/0.3	Hickory Cr. @ Harbor Ave.	2007	10	25	0.2	6.6	13.5	7.7		0.0499		0.2			0.2	5
PSF	442/1.5/0.3	Hickory Cr. @ Harbor Ave.	2007	12	21	11.5	1		7.9		0.0499		2.4			0.16	9
PSF	442/1.5/0.3	Hickory Cr. @ Harbor Ave.	2008	1	30	11	0.5		7.9		0.19		1.8			0.49	314
PSF	442/1.5/0.3	Hickory Cr. @ Harbor Ave.	2008	3	26	5	7		8.1		0.0499		0.7			0.1	1.99
PSF	442/1.5/0.3	Hickory Cr. @ Harbor Ave.	2008	4	29	15	8	7.8	8.1		0.0499		0.8			0.15	27
PSF	442/1.5/0.3	Hickory Cr. @ Harbor Ave.	2008	5	29	3.6	15	12.6	8		0.0499		0.9			0.13	15
PSF	442/1.5/0.3	Hickory Cr. @ Harbor Ave.	2008	6	26	320	22	10.8	7.7		0.0499		0.4			0.67	567
PSF	442/1.5/0.3	Hickory Cr. @ Harbor Ave.	2008	7	30	75	22.8	8.8	7.9		0.0499		0.3			0.25	94

Org	Site	Site Name	Year	Mo	Day	Flow	C	DO	pH	SC	NH3N	TKN	NO3N	TN	PO4	TP	TSS
PSF	442/1.5/0.3	Hickory Cr. @ Harbor Ave.	2008	8	29	16.2	19.3	7.9	8.1		0.0499		0.099			0.22	105
MDNR	??	Below 202 St	2008	9	25	7.02	18.9	7.1	7.7	318	0.0499		0.13	1.03		0.24	
PSF	442/1.5/0.3	Hickory Cr. @ Harbor Ave.	2008	9	26	10	17.9	8.1	7.8		0.0499		0.099			0.24	14
PSF	442/1.5/0.3	Hickory Cr. @ Harbor Ave.	2008	10	30	10	8.1	10.3	7.9		0.0499		0.099			0.09	4
PSF	442/1.5/0.3	Hickory Cr. @ Harbor Ave.	2008	11	25	7.8	2.1	12	8.2		0.0499		0.3			0.05	1.99
MDNR	442/1.5/0.3	Hickory Cr. @ Harbor Ave.	2009	4	20	3	16.6	10.5	8.4	398							9
MDNR	442/1.5/0.3	Hickory Cr. @ Harbor Ave.	2009	3	11	4	3.4	12.4	8.4	341							274
MDNR	442/1.5/0.3	Hickory Cr. @ Harbor Ave.	2009	2	27	4	2.1	12.5	8.5	323							277
MDNR	442/1.5/0.3	Hickory Cr. @ Harbor Ave.	2009	2	18	2.34	1.7	12.3		554							12
MDNR	442/1.2	Hickory Cr. bl. 202 St.	2009	4	8	6.75	10.1	11.7	8.4	472	0.015		0.52	0.77		0.005	11
MDNR	442/ less than above	Hickory Cr. Further DS of bl. 202 St.	2009	4	8	6.75	11.2	11.7	8.2	470	0.015		0.5	0.87		0.03	14
MDNR	442/1.5/0.3	Hickory Cr. @ Harbor Ave.	2009	5	6	2	16.6	9.2	8.3	513							14
MDNR	442/1.5/0.3	Hickory Cr. @ Harbor Ave.	2009	5	26	8	18.7	8.1	8.3	407							204

Note: CG=Continental Grain; SPF=Premium Standard Farms; C=Temperature in degrees Celsius, DO=dissolved oxygen, SC=specific conductivity in micromohs/centimeter (μmohs/cm), NH3N=ammonia as nitrogen, TKN=total Kjeldahl nitrogen, NO3N=nitrate plus nitrite as nitrogen, TN=total nitrogen, PO4=phosphate, TP=total phosphorus, TSS=total suspended solids

Appendix B
Development of Suspended Sediment Targets using Reference Load Duration Curves

Overview

This procedure is used when a lotic[10] system is placed on the 303(d) List for a pollutant and the designated use being addressed is aquatic life. In cases where pollutant data for the impaired stream is not available a reference approach is used. The target for pollutant loading is the 25th percentile calculated from all data available within the ecological drainage unit (EDU) in which the water body is located. Additionally, it is also unlikely that a flow record for the impaired stream is available. If this is the case, a synthetic flow record is needed. In order to develop a synthetic flow record calculate an average of the log discharge per square mile of USGS gaged rivers for which the drainage area is entirely contained within the EDU. From this synthetic record develop a flow duration from which to build a load duration curve for the pollutant within the EDU.

From this population of load durations follow the reference method used in setting nutrient targets in lakes and reservoirs. In this methodology the average concentration of either the 75th percentile of reference lakes or the 25th percentile of all lakes in the region is targeted in the TMDL. For most cases available pollutant data for reference streams is also not likely to be available. Therefore follow the alternative method and target the 25th percentile of load duration of the available data within the EDU as the TMDL load duration curve. During periods of low flow the actual pollutant concentration may be more important than load. To account for this during periods of low flow the load duration curve uses the 25th percentile of EDU concentration at flows where surface runoff is less than 1 percent of the stream flow. This result in an inflection point in the curve below which the TMDL is calculated using load calculated with this reference concentration.

Methodology

The first step in this procedure is to locate available pollutant data within the EDU of interest. These data along with the instantaneous flow measurement taken at the time of sample collection for the specific date are recorded to create the population from which to develop the load duration. Both the date and pollutant concentration are needed in order to match the measured data to the synthetic EDU flow record.

Secondly, collect average daily flow data for gages with a variety of drainage areas for a period of time to cover the pollutant record. From these flow records normalize the flow to a per square mile basis. Average the log transformations of the average daily discharge for each day in the period of record. For each gage record used to build this synthetic flow record calculate the Nash-Sutcliffe statistic to determine if the relationship is valid for each record. This relationship must be valid in order to use this methodology. This new synthetic record of flow per square mile is used to develop the load duration for the EDU. The flow record should be of sufficient length to be able to calculate percentiles of flow.

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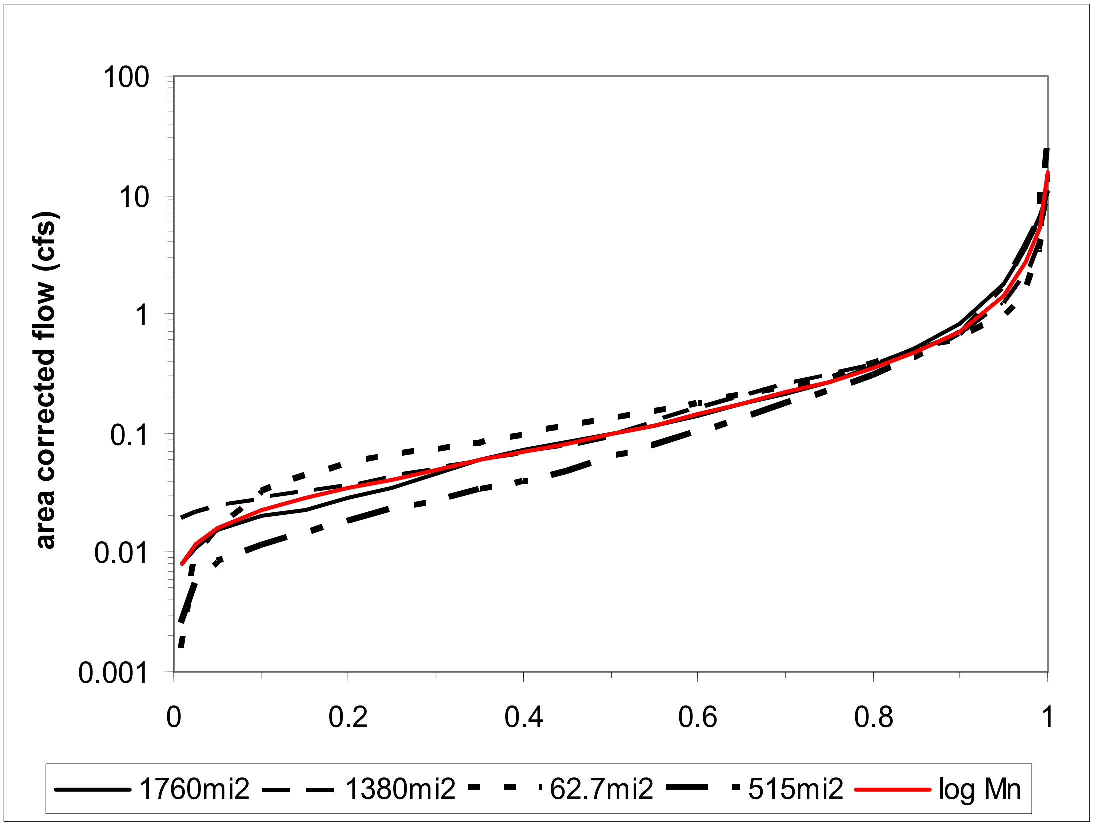
[10] Lotic = pertaining to moving water

The following examples show the application of the approach to one Missouri EDU.

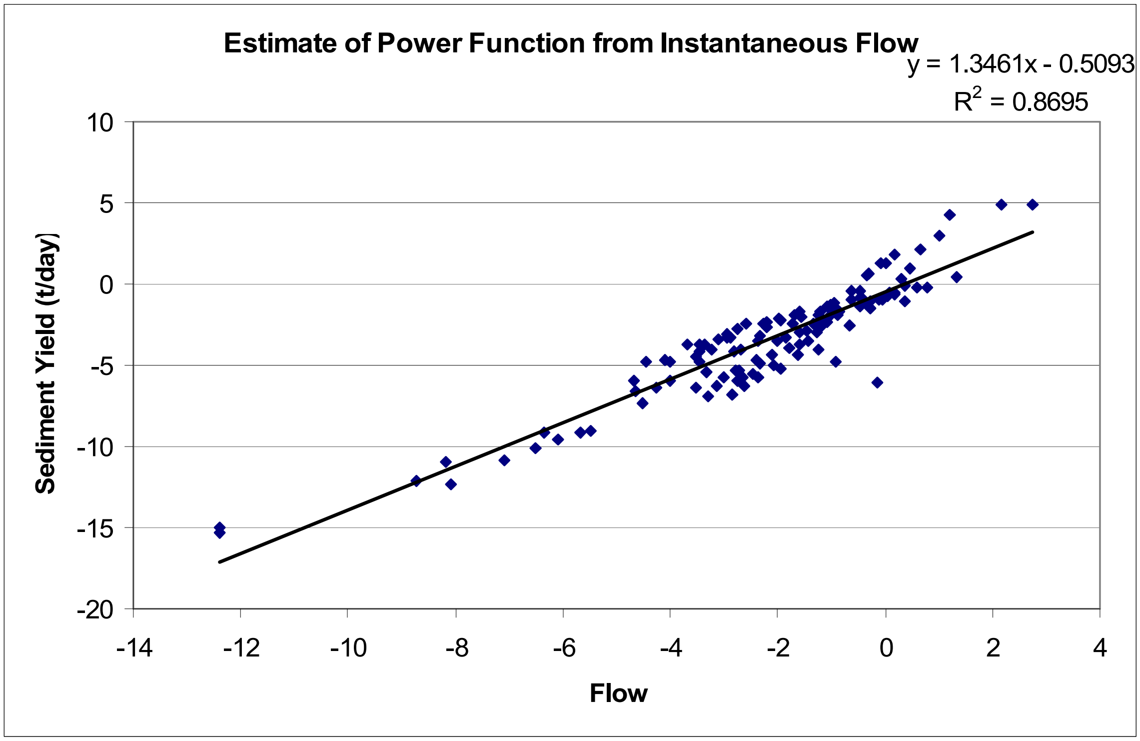
The watershed-size normalized data for the individual gages in the EDU were calculated and compared to a pooled data set including all of the gages. The results of this analysis are displayed in the following figure and table:



Gage	gage	area (mi^2)	normal Nash-Sutcliffe	lognormal Nash-Sutcliffe
Platte River	06820500	1760	80%	99%
Nodaway River	06817700	1380	90%	96%
Squaw Creek	06815575	62.7	86%	95%
102 River	06819500	515	99%	96%

This demonstrates the pooled data set can confidently be used as a surrogate for the EDU analyses.

The next step is to calculate pollutant-discharge relationships for the EDU, these are log transformed data for the yield (tons/mi^2/day) and the instantaneous flow (cfs/mi^2.) The following graph shows the EDU relationship:



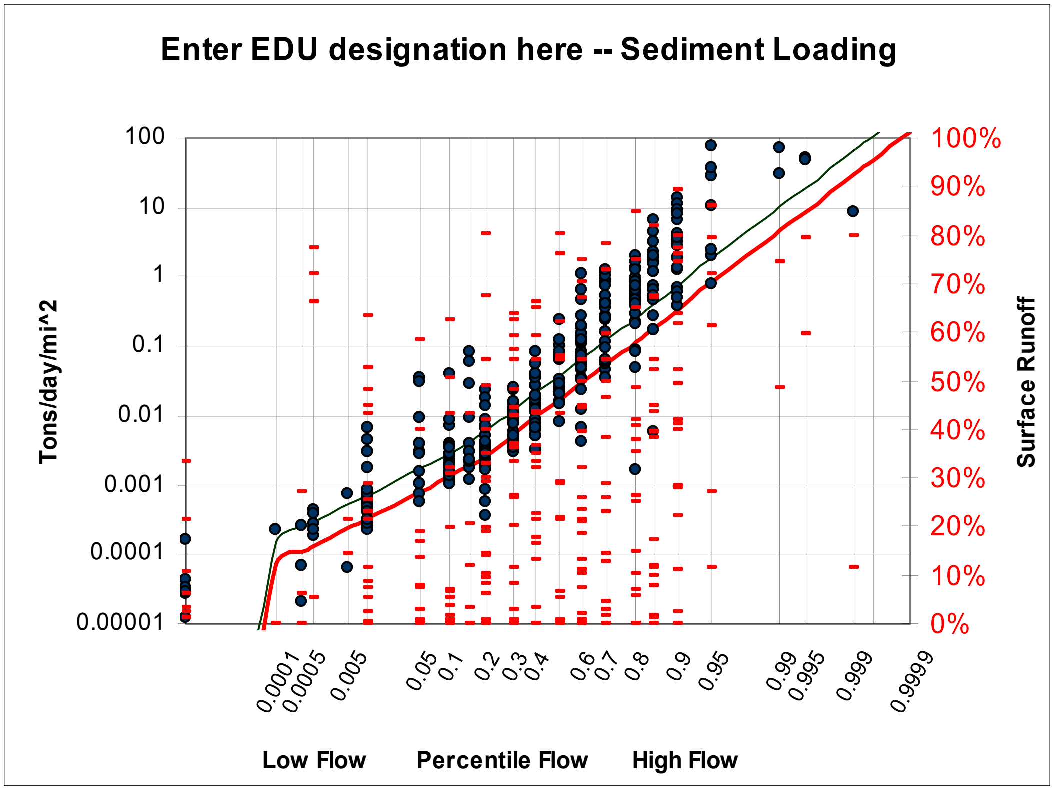
Further statistical analyses on this relationship are included in the following Table:

m	1.34608498	b	-0.509320019
Standard Error (m)	0.04721684	Standard Error (b)	0.152201589
r^2	0.86948229	Standard Error (y)	1.269553159
F	812.739077	DF	122
SSreg	1309.94458	SSres	196.6353573

The standard error of y was used to estimate the 25 percentile level for the TMDL line. This was done by adjusting the intercept (b) by subtracting the product of the one-sided Z_{75} statistic times the standard error of (y). The resulting TMDL Equation is the following:

*Sediment yield (t/day/mi^2) = exp (1.34608498 * ln (flow) - 1.36627)*

A resulting pooled TMDL of all data in the watershed is shown in the following graph:



To apply this process to a specific watershed would entail using the individual watershed data compared to the above TMDL curve that has been multiplied by the watershed area. Data from the impaired segment is then plotted as a load (tons/day) for the y-axis and as the percentile of flow for the EDU on the day the sample was taken for the x-axis.

For more information contact:
Environmental Protection Agency, Region 7
Water, Wetlands, and Pesticides Division
Total Maximum Daily Load Program
901 North 5th Street
Kansas City, Kansas 66101
Website: http://www.epa.gov/region07/water/tmdl.htm

Appendix C

Development of Nutrient Targets using EPA Recommended Ecoregion Nutrient Criteria with Load Duration Curves

Overview

This procedure is used when a lotic system is placed on the 303(d) impaired water body list for nutrient pollution and the designated use being addressed is aquatic life. In cases where U.S. Environmental Protection Agency (EPA) approved state numeric criteria for the impaired stream is not available, a reference approach is used. The target for pollutant loading is the EPA recommended ecoregion nutrient criterion for the specific ecoregion in which the water body is located (USEPA, 2000). If a flow record for the impaired stream is not available a synthetic flow record is needed. To develop a synthetic flow record a user should calculate an average of the log discharge per square mile of U.S. Geological Survey (USGS) gaged rivers for which the drainage area is contained within the ecological drainage unit (EDU) (Table C.1). From this synthetic record develop a flow duration and build a load duration curve (LDC) for the pollutant within the EDU.

See USEPA (2000) for more detailed information as to how recommended ecoregion nutrient criteria were developed. This appendix describes how the nutrient criteria (TN and TP) are expressed in this TMDL.

Methodology

The first step in this procedure is to gather available nutrient data within the ecoregion of interest (Tables C.2. and C.3). These data, along with the instantaneous flow measurement taken at the time of sample collection for the specific date, are required to develop the LDC. Both dates and nutrient concentrations are needed in order to match the measured data used with the synthetic EDU flow record.

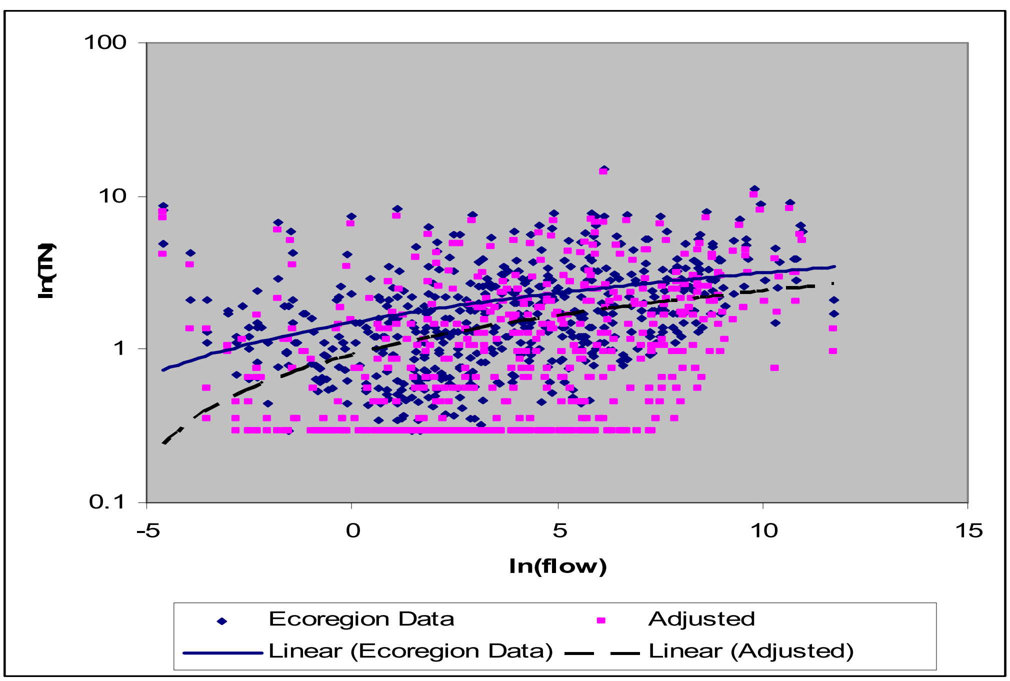
Secondly, collect average daily flow data from gages with a variety of drainage areas for a period of time to cover the nutrient record. From these flow records normalize the flow to a per square mile basis. Average the log transformations of the average daily discharge for each day in the period of record. For each gage record used to build the synthetic flow record calculate the Nash-Sutcliffe value to determine if the relationship is valid for each record. This relationship must be valid in order to use this methodology. This new synthetic record of flow per square mile is then used to develop the LDC for the EDU. The flow record should be of sufficient length to be able to calculate percentiles of flow (typically 20 years or more).

Table C.1. U.S. Geological Survey Gages used to develop synthetic flow regime for Ecoregion Level III 40, Central Irregular Plains

Gage Number	Gage Name	Drainage Area	Time Periods Used
USGS 06897000	East Fork Big Creek near Bethany, MO	95	10/01/1996 - 09/30/2009
USGS 06899500	Thompson River at Trenton, MO	1720	10/01/1989- 09/30/2009
USGS 06900050	Medicine Creek near Laredo, MO	355	11/14/2000 - 09/30/2009
USGS 06901500	Locust Creek near Linneus, MO	550	07/14/2000 - 09/30/2009

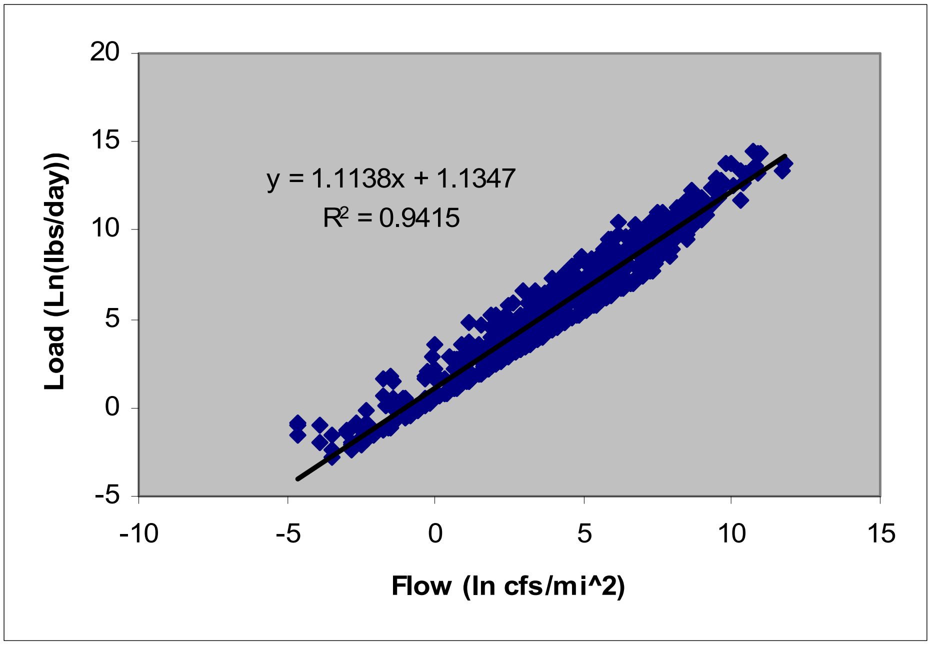
The next step was to collect previously measured water quality data from within the ecoregion. In the following example, measured TN concentrations are adjusted so their median is equal to the EPA recommended ecoregion TN criterion. This is accomplished by subtracting the difference between the EPA recommended ecoregion TN criterion and the median from the measured data. This results in the data retaining most of its natural variability yet having a median which meets the EPA recommended ecoregion TN criterion. Where this adjustment would result in a negative concentration the minimum measured concentration is substituted. Figure C.1 shows an example of this process where the solid line is the measured distribution of the natural log TN concentration with the natural log flow and the dashed line represents a data distribution (the adjusted data) which would comply with the EPA recommended ecoregion TN criterion.

Figure C.1. Graphic Representation of Data Adjustment



The next step was to calculate the TN-discharge relationship for the ecoregion using the adjusted data, this is natural log transformed data for the yield (pounds/mi^2/day) and the instantaneous flow (cfs/mi^2). Figure C.2 shows this relationship for this example TMDL.

Figure C.2. Load / Flow Relationship Used to Set Load Duration Curve TMDL



This relationship was used to develop a LDC for which the relationship between flow and nutrient distribution is taken into account. In this LDC the targeted concentration is allowed to change at different percentiles of flow exceedance. However, meeting the LDC will result in a water body in which the median concentration is equal to the EPA recommended ecoregion criterion.

To apply this process to a specific watershed entails using the individual watershed data compared to the TMDL curve that has been multiplied by the watershed area (mi^2). Data from the impaired segment is then plotted as a load (pounds/day) for the y-axis and as the percentile of flow for the EDU on the day the sample was taken for the x-axis. These data points do not have to be collected at the segment outlet. The spreadsheet applies an outlet flow (percentile exceedance) to the concentration based on the synthetic flow estimate for the specific date the sample was taken.

The resulting LDC with plotted site specific measured data can now be used to target implementation by identifying flows in which TN concentrations are higher than would be expected in a stream meeting the EPA recommended ecoregion TN criterion. See LDCs in TMDL, Figures 4 and 5.

Table C.2. Sites for water quality data (This information, except for drainage area, is in the following table).

Gage#	Name	Drainage Area
6898100	Thompson River at Mount Moriah, MO	891
6898800	Weldon River near Princeton, MO	452
6899580	No Creek near Dunlap, MO	34
6899585	No Creek at Farmersville, MO (n=1)	67.4
6899950	Medicine Creek near Harris, MO	192
6900100	Little Medicine Creek near Harris, MO	66.5
6901500	Locust Creek near Linneus, MO	550
6902000	Grand River near Summner, MO	6880
6905725	Mussel Fork near Mystic, MO	24

Table C.3. Data used to develop TSS targets and to develop distribution for nutrient targets (Where data are estimated (E) the estimate was used. Where data was less than the limit of detection [<] a value one half the limit of detection was used.)

USGS Gage Number	Sample Date	Flow (cfs)	NFR (mg/L)	Total Nitrogen (mg/L)	Total Phosphorus (mg/L)
Thompson River at Mount Moriah, MO					
6898100	11/9/1999	22	527		0.86
6898100	1/13/2000	8.6		0.7	E 0.04
6898100	3/23/2000	33			0.26
6898100	5/18/2000	19	27		0.14
6898100	7/13/2000	49			0.2
6898100	9/6/2000	10			0.53
6898100	11/28/2000	15	< 10	0.77	E 0.03
6898100	1/3/2001	7.5		0.75	< 0.06
6898100	3/15/2001	4860		5.6	1.92
6898100	5/2/2001	276	156	1.7	0.26
6898100	7/13/2001	126			0.16
6898100	9/20/2001	53		E 0.67	0.11
6898100	11/8/2001	41	14		E 0.06
6898100	1/17/2002	14	< 10	0.74	E 0.03
6898100	3/14/2002	91	43	1.9	0.1
6898100	5/9/2002	223	347	1.8	0.39
6898100	8/1/2002	26	30		0.12
6898100	9/3/2002	17	176		0.3
6898100	11/7/2002	18	< 10		0.05
6898100	1/15/2003	15	< 10		E 0.04
6898100	3/28/2003	50	11	0.68	0.07
6898100	5/22/2003	196	107	5.1	0.22
6898100	7/15/2003	76	66	1.4	0.28
6898100	8/29/2003	6.1	< 10		0.08
6898100	9/4/2003	10	146		0.34
6898100	11/4/2003	325	644	4	1.08
6898100	1/23/2004	23	< 10	0.82	E 0.04

USGS Gage Number	Sample Date	Flow (cfs)	NFR (mg/L)	Total Nitrogen (mg/L)	Total Phosphorus (mg/L)
6898100	3/25/2004	268	186	5	0.3
6898100	5/20/2004	E 837	593	7.6	1.03
6898100	7/9/2004	118	17	2.8	0.28
6898100	9/10/2004	259	82	1.2	0.26
6898100	11/8/2004	70	132		0.24
6898100	1/21/2005	31	< 10	0.95	E 0.03
6898100	3/3/2005	144	42	2.4	0.09
6898100	5/25/2005	342	292	3.8	0.39
6898100	7/8/2005	96	67		0.19
6898100	9/16/2005	23	< 10	E 0.32	0.05
6898100	11/10/2005	12	< 10		0.04
6898100	1/20/2006	23	< 10		0.04
6898100	3/31/2006	23	< 10		0.04
6898100	5/25/2006	81	100		0.22
6898100	7/27/2006	15	23		0.1
6898100	9/8/2006	44	28		0.13
6898100	11/9/2006	23	< 10		0.05
6898100	1/4/2007	381	333	7.4	0.77
6898100	2/14/2007	24	< 10	3.9	E 0.03
6898100	3/21/2007	291	218	3.4	0.32
6898100	4/6/2007	394	192	3.2	0.3
6898100	5/23/2007	298	63	3.3	0.17
6898100	6/20/2007	133	82	2.1	0.18
6898100	7/25/2007	54	17		0.09
6898100	9/19/2007	132	26	E 0.83	0.1
6898100	11/16/2007	137	48	2.1	0.14
6898100	1/24/2008	200	20	2.4	0.07
6898100	3/12/2008	682	328	2.9	0.55
6898100	5/29/2008	481	196	3.4	0.29
6898100	7/10/2008	1280	1440	5.2	1.52
6898100	9/17/2008	569	300	1.7	0.43
6898100	10/22/2008	1380	2930	5.2	2.44
6898100	1/14/2009	235	74	1.7	0.09
6898100	3/5/2009	264	254	2.2	0.35
6898100	5/7/2009	614	336	3.1	0.45
6898100	7/16/2009	1220	718	3.2	0.64
6898100	9/3/2009	288	109	1.2	0.25
Weldon River near Princeton, MO					
6898800	11/9/1999	5.3		0.29	0.043
6898800	1/11/2000	10		0.38	< 0.05
6898800	3/21/2000	13			E 0.03
6898800	5/16/2000	2.4	< 10		< 0.05
6898800	7/11/2000	9.4			0.09
6898800	9/6/2000	1.8			0.07
6898800	11/30/2000	5.2	< 10	0.6	< 0.060
6898800	1/5/2001	8.1		0.54	< 0.06
6898800	3/15/2001	2840		3.9	1.28

USGS Gage Number	Sample Date	Flow (cfs)	NFR (mg/L)	Total Nitrogen (mg/L)	Total Phosphorus (mg/L)
6898800	5/2/2001	152	119	2.5	0.24
6898800	7/11/2001	63			0.13
6898800	9/18/2001	18		E 0.35	< 0.06
6898800	11/6/2001	36	18	0.6	0.1
6898800	1/15/2002	20	< 10	0.57	< 0.06
6898800	3/12/2002	101	114	2.6	0.21
6898800	5/7/2002	527	210	2.3	0.5
6898800	7/30/2002	17	14		0.07
6898800	8/15/2002	8.7	20		0.07
6898800	9/5/2002	3.3	13		E 0.04
6898800	10/24/2002	5	< 10	E 0.34	E 0.03
6898800	11/5/2002	6.5	< 10		< 0.04
6898800	12/10/2002	4.3	< 10	E 0.29	E 0.02
6898800	1/14/2003	1.9	< 10		E 0.02
6898800	3/7/2003	8.6	< 10	0.64	E 0.03
6898800	3/26/2003	7.3	< 10		0.04
6898800	5/20/2003	168	264	1.7	0.33
6898800	7/17/2003	6.1	19		0.08
6898800	9/5/2003	0.73	52		< 0.04
6898800	11/6/2003	99	120	4.5	0.5
6898800	1/21/2004	30	19	2.5	0.13
6898800	3/23/2004	90	39	1.7	0.12
6898800	5/18/2004	473	267	15	1.73
6898800	7/7/2004	44	14		0.08
6898800	9/8/2004	166	85	0.86	0.2
6898800	11/10/2004	20	< 10	E 0.35	E 0.03
6898800	1/19/2005	11	< 10	0.59	< 0.04
6898800	3/1/2005	80	51	1.1	0.07
6898800	5/23/2005	128	266	2.2	0.34
6898800	7/6/2005	23	< 10		E 0.04
6898800	9/14/2005	6	10		0.05
6898800	11/8/2005	6.5	21		0.04
6898800	1/18/2006	9.4	< 10		< 0.04
6898800	3/31/2006	117	750	3	0.8
6898800	5/23/2006	6.1	12		0.04
6898800	7/25/2006	1.5	60		0.11
6898800	9/6/2006	9.2	42		0.08
6898800	11/7/2006	5.5	< 10		0.06
6898800	1/4/2007	82	44	3.7	0.23
6898800	2/16/2007	7.2	< 10	0.42	E 0.03
6898800	3/23/2007	625	1250	5.5	1.52
6898800	4/6/2007	174	86	1.4	0.15
6898800	5/23/2007	97	28	1	0.09
6898800	6/20/2007	35	31		0.12
6898800	7/25/2007	19	15		0.07
6898800	9/19/2007	42	24		0.07
6898800	11/14/2007	24	13	E 0.46	0.06

USGS Gage Number	Sample Date	Flow (cfs)	NFR (mg/L)	Total Nitrogen (mg/L)	Total Phosphorus (mg/L)
6898800	1/24/2008	60	140	1.6	0.26
6898800	3/12/2008	615	472	1.9	0.48
6898800	5/29/2008	166	79	1.2	0.17
6898800	7/10/2008	307	426	2.8	0.6
6898800	9/17/2008	325	364	1.4	0.41
6898800	10/22/2008	6480	1850	4.9	1.93
6898800	1/14/2009	78	< 15	0.92	E 0.04
6898800	3/6/2009	121	112	0.76	0.14
6898800	5/7/2009	260	126	1.2	0.21
6898800	7/16/2009	98	54		0.16
6898800	9/3/2009	274	145	1.1	0.26
No Creek near Dunlap					
6899580	1/22/1998	3.7	1		
6899580	6/2/1998	3.2	51		
6899580	3/30/1999	4.4		0.48	E 0.05
6899580	4/22/1999	14		0.77	0.13
6899580	6/21/1999	0.25	70		0.14
6899580	10/25/1999	0.01		8.6	0.19
6899580	11/29/1999	0.01	73		0.24
6899580	12/20/1999	0.1			0.09
6899580	1/24/2000	0.1	28	1.4	0.12
6899580	2/23/2000	0.06			0.14
6899580	4/20/2000	0.81			0.16
6899580	5/9/2000	0.17	54	6.7	0.3
6899580	6/14/2000	6.4		6.3	0.46
6899580	6/22/2000	0.4		1.3	0.18
6899580	7/25/2000	0.11	45	1.4	0.15
6899580	10/24/2000	0.37		1.6	0.67
6899580	11/15/2000	0.68	21	2.1	0.14
6899580	12/19/2000	0.08		E 1.4	E 0.06
6899580	1/24/2001	1.6	18	2.9	0.1
6899580	2/15/2001	40		2.8	0.34
6899580	3/27/2001	10		1.6	0.12
6899580	4/24/2001	19		1.3	0.18
6899580	5/22/2001	9.9	41	1.3	0.15
6899580	6/19/2001	2.7		1.6	0.23
6899580	6/25/2001	5.2		1.1	0.18
6899580	7/26/2001	59	290	1.7	0.35
6899580	8/9/2001	0.47		E 0.75	0.12
6899580	9/13/2001	0.1		E 2.4	0.15
6899580	10/23/2001	38	386	2.3	0.72
6899580	11/29/2001	0.28	78		0.19
6899580	12/13/2001	1	20		0.1
6899580	2/28/2002	1.7	22	1.2	0.07
6899580	3/21/2002	2.1	< 10		E 0.03
6899580	4/18/2002	4.3	36	0.75	0.12
6899580	5/23/2002	2.4	< 10	E 0.51	0.07

USGS Gage Number	Sample Date	Flow (cfs)	NFR (mg/L)	Total Nitrogen (mg/L)	Total Phosphorus (mg/L)
6899580	6/13/2002	0.53	20	0.64	0.1
6899580	6/28/2002	0.07	40		0.11
6899580	7/23/2002	0.01	< 10	E 8.0	0.17
6899580	8/22/2002	1	44	7.3	0.91
6899580	12/19/2002	0.01	37		0.16
6899580	3/13/2003	0.41	< 10		0.17
6899580	3/20/2003	0.34	12		0.15
6899580	4/25/2003	2.1	82	1.2	0.22
6899580	4/30/2003	0.62	12		0.14
6899580	5/6/2003	6.4	164	3.5	0.38
6899580	6/12/2003	3	68	8.2	0.24
6899580	7/9/2003	0.01	43	4.9	0.27
6899580	9/19/2003	0.26	144	1.1	0.28
6899580	10/23/2003	0.03	70		0.28
6899580	11/18/2003	0.1	23		0.22
6899580	12/11/2003	22	120	3.7	0.43
6899580	1/8/2004	1	17	2.3	0.11
6899580	2/27/2004	5.8	14	1.9	0.11
6899580	3/18/2004	52	117	2	0.25
6899580	4/20/2004	2.7	33		0.1
6899580	5/11/2004	1.3	< 10		0.08
6899580	6/22/2004	9.1	49	1.1	0.17
6899580	7/16/2004	0.41	23	E 0.78	0.14
6899580	8/23/2004	0.72	67	E 0.77	0.14
6899580	9/14/2004	0.76	520	E 2.6	0.79
6899580	10/26/2004	1	< 10		0.28
6899580	11/16/2004	3.7	< 10	0.46	0.06
6899580	12/14/2004	6.2	18	0.65	0.08
6899580	1/25/2005	0.08	18	1.2	0.14
6899580	2/10/2005	21	138	1.4	0.16
6899580	3/17/2005	2.9	< 10		E 0.04
6899580	4/5/2005	3.6	< 10		0.04
6899580	5/12/2005	2	52		0.14
6899580	6/30/2005	0.86	24	0.73	0.12
6899580	7/13/2005	0.03	< 10		0.06
6899580	8/19/2005	0.02	33		0.09
6899580	9/21/2005	0.05	53		0.12
6899580	10/5/2005	0.08	380		0.49
6899580	11/3/2005	0.01	1510		1.94
6899580	12/14/2005	0.1	44	E 1.5	0.19
6899580	1/25/2006	0.03	43		0.11
6899580	2/14/2006	0.01	22		0.1
6899580	3/9/2006	0.2	< 10		0.07
6899580	4/12/2006	2.1	72	0.95	0.16
6899580	5/9/2006	2.8	44	0.93	0.13
6899580	6/15/2006	0.23	24	5.8	0.13
6899580	7/19/2006	0	152		0.59

USGS Gage Number	Sample Date	Flow (cfs)	NFR (mg/L)	Total Nitrogen (mg/L)	Total Phosphorus (mg/L)
6899580	8/10/2006	3.1	147	1.6	0.34
6899580	9/21/2006	0.02	170	E 4.3	0.31
6899580	10/25/2006	0.02	93	E 2.1	0.35
6899580	12/13/2006	0.52	17	0.92	0.12
6899580	1/26/2007	0.84	< 10	1	E 0.04
6899580	2/20/2007	56	162	3.8	0.68
6899580	3/15/2007	8.1	37	1.2	0.09
6899580	4/27/2007	76	225	2.9	0.38
6899580	5/10/2007	18	110	2.7	0.23
6899580	6/28/2007	19	485	7.6	0.64
6899580	7/19/2007	E 0.03	165	E 1.3	0.21
6899580	8/23/2007	0.24	75	1.5	0.21
6899580	9/27/2007	0.19	105		0.25
6899580	10/16/2007	0.06	136	E 1.2	0.36
6899580	11/8/2007	0.01	16		0.28
6899580	12/20/2007	3.1	20	2.2	0.14
6899580	1/10/2008	22	58	2	0.23
6899580	2/26/2008	E 65	86	2.9	0.35
6899580	3/25/2008	8.3	34	0.95	0.1
6899580	4/16/2008	11	102	1.2	0.18
6899580	5/22/2008	2.1	138	E 1.0	0.22
6899580	6/17/2008	13	74	1.3	0.22
6899580	7/15/2008	0.8	46	1.1	0.14
6899580	8/12/2008	0.55	24	E 0.54	0.1
6899580	9/23/2008	3	< 10	0.44	0.09
6899580	10/28/2008	6.6	< 15	0.65	0.13
6899580	11/18/2008	11	< 15	0.65	0.1
6899580	12/2/2008	5.8	< 15	0.54	0.07
6899580	1/27/2009	1.9	< 15	E 0.34	E 0.04
6899580	2/24/2009	3	16		0.05
6899580	3/12/2009	16	250	2.1	0.34
6899580	4/24/2009	6.5	16	E 0.48	0.08
6899580	5/15/2009	29	730	2.7	0.65
6899580	6/23/2009	20	< 150	1.8	0.27
6899580	8/18/2009	56	266	2	0.38
No Creek at Farmersville, MO					
6899585	11/16/2006	0.13	< 10	0.44	0.26
Medicine Creek near Harris, MO					
6899950	10/26/1999	2.3			E 0.045
6899950	11/30/1999	3	6		< 0.05
6899950	12/21/1999	0.1		0.65	< 0.05
6899950	1/25/2000	0.5	3		< 0.05
6899950	2/22/2000	15			E 0.04
6899950	3/27/2000	8.7			E 0.03
6899950	4/18/2000	4			E 0.03
6899950	5/10/2000	10	< 10		0.05
6899950	6/21/2000	6		0.87	0.08

USGS Gage Number	Sample Date	Flow (cfs)	NFR (mg/L)	Total Nitrogen (mg/L)	Total Phosphorus (mg/L)
6899950	7/26/2000	6.6	37		0.11
6899950	9/20/2000	3.4		0.54	0.07
6899950	10/26/2000	6.1			0.07
6899950	11/14/2000	5.8	< 10	0.93	0.09
6899950	12/18/2000	3.1		E 0.34	< 0.06
6899950	1/25/2001	12	< 10	3.2	0.11
6899950	2/13/2001	131		2.8	0.3
6899950	3/29/2001	100		2	0.21
6899950	4/26/2001	76		1	0.21
6899950	5/24/2001	52	68	1.3	0.18
6899950	6/19/2001	79		1.5	0.33
6899950	6/26/2001	60		1.1	0.18
6899950	7/25/2001	353	1610	3.2	1.34
6899950	8/8/2001	13		E 0.55	0.09
6899950	9/12/2001	7.4		0.5	0.07
6899950	10/25/2001	33	118	2.6	0.37
6899950	11/28/2001	3.4	12	E 0.35	E 0.03
6899950	12/12/2001	6.2			< 0.06
6899950	1/3/2002	4.6	< 10	0.55	< 0.06
6899950	1/8/2002	5	< 10	E 0.45	< 0.06
6899950	2/27/2002	9.9	12	1.3	0.07
6899950	3/19/2002	18	< 10		0.06
6899950	4/17/2002	68	130	1.4	0.24
6899950	5/21/2002	38	38	1	0.1
6899950	6/28/2002	5.6	13		E 0.06
6899950	7/24/2002	3.6	< 10		0.08
6899950	8/21/2002	17	41		0.14
6899950	9/10/2002	1.4	< 10		E 0.05
6899950	10/17/2002	1.4	< 10		E 0.03
6899950	11/19/2002	2	< 10		E 0.03
6899950	12/18/2002	2.8	< 10		0.04
6899950	1/30/2003	0.9	< 10		E 0.03
6899950	2/20/2003	3.4	< 10		E 0.03
6899950	3/12/2003	3.9	< 10		0.1
6899950	4/23/2003	14	12		0.25
6899950	5/8/2003	27	104	2.9	0.29
6899950	6/11/2003	51	282	5.8	0.47
6899950	7/10/2003	65	161	1.5	0.3
6899950	8/25/2003	0.61	< 10		0.06
6899950	9/17/2003	4.5	49	1.4	0.36
6899950	10/22/2003	1.3	< 10		0.05
6899950	11/20/2003	3	< 10		0.06
6899950	12/10/2003	368	E 692	5.5	2.81
6899950	1/7/2004	6.2	< 10	1.7	0.06
6899950	2/26/2004	55	66	2.4	0.34
6899950	3/16/2004	71	53	1.7	0.22
6899950	4/22/2004	21	12		0.06

USGS Gage Number	Sample Date	Flow (cfs)	NFR (mg/L)	Total Nitrogen (mg/L)	Total Phosphorus (mg/L)
6899950	5/13/2004	11	< 10		0.05
6899950	6/23/2004	42	49	1.2	0.18
6899950	7/14/2004	32	76	1.3	0.24
6899950	8/25/2004	378	1700	4.9	1.77
6899950	9/16/2004	25	15		0.1
6899950	10/27/2004	50	131	1.5	0.31
6899950	11/18/2004	16	< 10		0.04
6899950	12/16/2004	26	< 10	0.82	0.05
6899950	1/27/2005	169	280	2.3	0.53
6899950	2/9/2005	105	165	2.2	0.25
6899950	3/16/2005	28	< 10		0.06
6899950	4/8/2005	77	79		0.21
6899950	5/11/2005	24	15		0.08
6899950	6/29/2005	77	620	5.6	1.27
6899950	7/12/2005	5.7	< 10		0.05
6899950	8/17/2005	6.2	< 10	0.71	0.06
6899950	9/20/2005	3.6	14	E 0.37	0.05
6899950	10/5/2005	2.8	11		0.04
6899950	11/2/2005	2	< 10		E 0.03
6899950	12/15/2005	4.4	< 10		E 0.02
6899950	1/26/2006	2.6	< 10		E 0.03
6899950	2/17/2006	1.3	< 10		0.04
6899950	3/8/2006	9.8	< 10		0.06
6899950	4/13/2006	12	15		0.08
6899950	5/10/2006	18	20	0.59	0.07
6899950	6/14/2006	2.4	< 10		0.04
6899950	7/18/2006	4.8	16		0.13
6899950	8/9/2006	16	150	1.5	0.38
6899950	9/20/2006	1.4	< 10		< 0.04
6899950	10/24/2006	3	< 10		0.08
6899950	11/15/2006	2.6	< 10		0.09
6899950	12/14/2006	4.4	24	1.5	0.07
6899950	1/25/2007	8	< 10	1.3	0.06
6899950	2/21/2007	460	379	7.4	1.37
6899950	3/14/2007	60	72	2	0.2
6899950	4/27/2007	971	660	4.5	1.19
6899950	5/9/2007	349	424	2.8	0.63
6899950	6/27/2007	10	19	0.65	0.08
6899950	7/18/2007	4.6	10		0.08
6899950	8/21/2007	57	763	3.2	0.93
6899950	9/25/2007	9.8	< 20		0.08
6899950	10/16/2007	46	84	1.2	0.25
6899950	11/6/2007	14	< 10	0.49	0.09
6899950	12/19/2007	57	35	1.7	0.13
6899950	1/9/2008	483	406	2.6	0.56
6899950	2/27/2008	202	140	3.5	0.45
6899950	3/26/2008	64	49	0.97	0.12

USGS Gage Number	Sample Date	Flow (cfs)	NFR (mg/L)	Total Nitrogen (mg/L)	Total Phosphorus (mg/L)
6899950	4/16/2008	119	170	1.5	0.27
6899950	5/21/2008	36	19		0.1
6899950	6/18/2008	112	148	1.4	0.28
6899950	7/16/2008	19	35		0.14
6899950	8/13/2008	25	46		0.1
6899950	9/24/2008	98	536	2.6	0.61
6899950	10/29/2008	60	39	0.92	0.17
6899950	11/19/2008	75	42	0.83	0.12
6899950	12/3/2008	49	16	0.61	0.06
6899950	1/28/2009	19	< 15	0.72	0.04
6899950	2/25/2009	34	22	0.61	0.06
6899950	3/11/2009	715	1180	4.9	1.37
6899950	4/22/2009	61	85	0.92	0.17
6899950	5/13/2009	377	1900	6.5	2.37
6899950	6/24/2009	75	220	2.4	0.42
6899950	7/22/2009	20	24		0.1
6899950	8/20/2009	180	455	2.2	0.54
Little Medicine Creek near Harris					
6900100	1/22/1998	8.7	1		
6900100	6/2/1998	11	26		
6900100	1/5/1999	4.8	5	0.67	< 0.05
6900100	3/31/1999	12		0.37	E 0.03
6900100	4/21/1999	35		1.1	0.16
6900100	6/22/1999	4.7	30	0.97	0.11
6900100	8/25/1999	0.62		0.56	E 0.04
6900100	10/26/1999	0.67			E 0.03
6900100	11/30/1999	0.73	1		< 0.05
6900100	12/21/1999	0.1		0.82	0.06
6900100	1/25/2000	0.5	4		< 0.05
6900100	2/22/2000	1.8			E 0.04
6900100	3/27/2000	1.1			< 0.05
6900100	4/18/2000	2			E 0.04
6900100	5/10/2000	1.4	< 10		E 0.03
6900100	6/21/2000	1.2		1.5	0.07
6900100	7/26/2000	1.6	< 10		0.07
6900100	9/20/2000	1.6			0.05
6900100	10/26/2000	1.8			0.08
6900100	11/14/2000	1.8	< 10	1	E 0.06
6900100	12/19/2000	0.91		0.44	E 0.04
6900100	1/25/2001	3.2	< 10	3.2	E 0.04
6900100	2/13/2001	46		3.2	0.42
6900100	3/29/2001	35		1.9	0.14
6900100	4/26/2001	18		0.87	0.15
6900100	5/24/2001	16	31	1.4	0.12
6900100	6/19/2001	17		1.9	0.26
6900100	6/26/2001	13		0.92	0.09
6900100	7/25/2001	11	444	4	0.48

USGS Gage Number	Sample Date	Flow (cfs)	NFR (mg/L)	Total Nitrogen (mg/L)	Total Phosphorus (mg/L)
6900100	8/8/2001	1.4		0.59	E 0.05
6900100	9/12/2001	1.2		0.79	0.07
6900100	10/25/2001	7.5	54	2.2	0.2
6900100	11/28/2001	1.5	< 10		< 0.06
6900100	12/12/2001	1.7	< 10		< 0.06
6900100	1/8/2002	0.38	< 10	0.8	< 0.06
6900100	2/27/2002	1.8	< 10	1.2	E 0.03
6900100	3/19/2002	2	< 10		< 0.06
6900100	4/17/2002	13	66	1	0.13
6900100	5/21/2002	9.1	14	0.67	0.07
6900100	6/28/2002	2	< 10	E 0.44	E 0.04
6900100	7/24/2002	0.59	< 10		E 0.04
6900100	8/21/2002	3.1	< 10	0.62	0.1
6900100	9/10/2002	0.15	< 10		E 0.04
6900100	10/17/2002	0.31	< 10		E 0.03
6900100	11/19/2002	0.41	< 10		0.06
6900100	12/18/2002	0.64	< 10		E 0.02
6900100	1/29/2003	0.11	< 10		0.05
6900100	2/20/2003	0.64	< 10		E 0.03
6900100	3/12/2003	1.4	< 10		< 0.04
6900100	4/23/2003	0.47	< 10	0.61	0.04
6900100	5/8/2003	3.5	127	2.4	0.19
6900100	6/11/2003	30	344	5.4	0.51
6900100	7/10/2003	138	E 2060	7.7	1.76
6900100	8/25/2003	0.08	13	E 0.64	0.1
6900100	9/18/2003	0.48	20	0.65	0.07
6900100	10/22/2003	0.3	< 10		0.07
6900100	11/20/2003	0.52	< 10		0.05
6900100	12/10/2003	98	470	6.5	0.93
6900100	1/7/2004	0.73	16	2.2	E 0.03
6900100	2/26/2004	10	36	2.2	0.11
6900100	3/16/2004	25	56	1.7	0.14
6900100	4/22/2004	4.6	< 10		0.04
6900100	5/13/2004	8.9	102	1.2	0.18
6900100	6/23/2004	12	33	1.3	0.13
6900100	7/14/2004	6	37	1.3	0.15
6900100	8/25/2004	2150	1400	5.8	1.91
6900100	9/16/2004	5.8	64	0.65	0.17
6900100	10/27/2004	16	146	1.3	0.29
6900100	11/18/2004	5.2	< 10		E 0.04
6900100	12/17/2004	4.6	< 10	0.85	E 0.03
6900100	1/27/2005	24	51	2.6	0.37
6900100	2/10/2005	7	48	1.8	0.11
6900100	3/16/2005	7.6	< 10		0.04
6900100	4/8/2005	15	18		0.07
6900100	5/12/2005	8.6	38	E 0.66	0.1
6900100	6/30/2005	6	20	E 0.73	0.1

USGS Gage Number	Sample Date	Flow (cfs)	NFR (mg/L)	Total Nitrogen (mg/L)	Total Phosphorus (mg/L)
6900100	7/12/2005	1.4	< 10	E 0.53	0.06
6900100	8/17/2005	0.42	< 10	0.64	0.06
6900100	9/20/2005	0.64	< 10		0.05
6900100	10/5/2005	0.22	< 10	E 0.29	E 0.04
6900100	11/2/2005	0.15	< 10		0.05
6900100	12/15/2005	1.6	< 10		E 0.03
6900100	1/26/2006	0.73	< 10		E 0.03
6900100	2/17/2006	0.37	< 10		E 0.04
6900100	3/8/2006	2.2	< 10		0.04
6900100	4/13/2006	1.5	15		0.07
6900100	5/10/2006	2.3	19		0.05
6900100	6/14/2006	0.43	< 10	0.53	0.05
6900100	7/19/2006	0.22	< 10	0.79	0.08
6900100	8/9/2006	3	122	1.2	0.25
6900100	9/20/2006	0.16	< 10		E 0.03
6900100	10/24/2006	0.35	< 10		0.06
6900100	11/16/2006	0.45	< 10		0.09
6900100	12/14/2006	1.1	13	1.5	0.06
6900100	1/25/2007	2.2	< 10	1.2	< 0.04
6900100	2/21/2007	E 130	59	6.2	1.16
6900100	3/15/2007	14	64	1.8	0.13
6900100	4/25/2007	1830	1070	7.3	2.42
6900100	5/10/2007	52	184	2.3	0.33
6900100	6/27/2007	1.4	10	0.56	0.06
6900100	7/18/2007	0.53	13		0.06
6900100	8/21/2007	14	663	5.6	0.92
6900100	9/25/2007	1.5	< 20	E 0.43	0.09
6900100	10/17/2007	13	424	2.2	0.81
6900100	11/8/2007	1	< 10		0.1
6900100	12/19/2007	13	31	2.2	0.15
6900100	1/10/2008	68	88	2.7	0.34
6900100	2/27/2008	58	82	3.2	0.37
6900100	3/26/2008	21	43	0.95	0.11
6900100	4/16/2008	33	88	1.4	0.21
6900100	5/21/2008	7.3	< 10		0.08
6900100	6/18/2008	20	74	1.3	0.21
6900100	7/16/2008	3	10	0.51	0.07
6900100	8/13/2008	3.3	13	0.48	0.08
6900100	9/24/2008	300	2200	5.7	1.81
6900100	10/29/2008	18	23	0.65	0.11
6900100	11/19/2008	30	33	1	0.11
6900100	12/3/2008	17	< 15	0.68	0.05
6900100	1/28/2009	4.5	< 15	0.73	E 0.03
6900100	2/25/2009	12	18	0.57	0.05
6900100	3/11/2009	118	490	3.4	0.56
6900100	4/22/2009	15	15	0.41	0.06
6900100	5/13/2009	352	1760	7.8	2.21

USGS Gage Number	Sample Date	Flow (cfs)	NFR (mg/L)	Total Nitrogen (mg/L)	Total Phosphorus (mg/L)
6900100	6/24/2009	26	160	2	0.29
6900100	7/22/2009	2.5	< 15	0.47	0.05
6900100	8/20/2009	176	1290	3.8	1.15
Locust Creek near Linneus, MO					
6901500	8/26/2003	0.8	<10		0.05
Grand River near Sumner, MO					
6902000	11/8/1989	373		1	0.13
6902000	1/18/1990	851		2.2	0.34
6902000	5/9/1990	5480		2.3	0.42
6902000	7/11/1990	1430		1.3	0.35
6902000	11/7/1990	1310		3.6	0.3
6902000	1/9/1991	452		2	0.24
6902000	5/17/1991	14200		2.6	0.39
6902000	7/16/1991	2510		3.2	0.41
6902000	11/6/1991	470		1.7	0.31
6902000	1/15/1992	2720		1.7	0.34
6902000	7/8/1992	340			0.11
6902000	11/12/1992	7780		2.2	0.22
6902000	12/2/1992	4980		1.4	0.28
6902000	1/6/1993	8980		1.9	0.47
6902000	2/17/1993	2510		1.4	0.25
6902000	3/17/1993	3220		1.5	0.28
6902000	4/8/1993	29800		1.5	0.22
6902000	5/12/1993	33700		3.7	0.2
6902000	6/16/1993	18400		11	1
6902000	7/27/1993	128000		2.1	0.55
6902000	8/25/1993	2820		1.3	
6902000	9/16/1993	23600		2.8	0.34
6902000	10/27/1993	1700		1.1	0.04
6902000	11/16/1993	3300		1.7	0.25
6902000	12/8/1993	1140			0.03
6902000	1/5/1994	755		0.92	0.05
6902000	2/3/1994	1200		2.7	0.18
6902000	3/16/1994	1750		1.8	0.18
6902000	3/30/1994	750		0.78	0.09
6902000	4/27/1994	900			0.12
6902000	5/10/1994	3700		2.6	0.28
6902000	6/14/1994	4500		5.2	1.2
6902000	8/23/1994	250			
6902000	9/14/1994	270			0.11
6902000	10/26/1994	136			0.13
6902000	11/30/1994	1200		2	0.15
6902000	12/14/1994	1140		1.8	0.2
6902000	1/5/1995	350		1.4	0.03
6902000	2/8/1995	2060		2.7	0.27
6902000	3/30/1995	2720		3.5	0.13
6902000	4/18/1995	5660		7.9	0.41

USGS Gage Number	Sample Date	Flow (cfs)	NFR (mg/L)	Total Nitrogen (mg/L)	Total Phosphorus (mg/L)
6902000	5/24/1995	51600		2.8	0.4
6902000	6/14/1995	4450		1.5	0.2
6902000	7/12/1995	6100		2.8	0.14
6902000	8/2/1995	2030		1.8	0.39
6902000	9/5/1995	496			0.13
6902000	10/24/1995	235			0.11
6902000	11/6/1995	595		1.2	0.1
6902000	12/13/1995	216		0.49	0.04
6902000	1/22/1996	430		1.1	0.08
6902000	2/14/1996	3050		2.5	1
6902000	3/26/1996	1480		2.4	0.31
6902000	4/16/1996	520			0.16
6902000	5/20/1996	4660		3.6	0.57
6902000	6/19/1996	14500		4.8	0.83
6902000	7/17/1996	1050			0.16
6902000	8/14/1996	906			0.12
6902000	9/11/1996	1170		1.6	0.14
6902000	10/9/1996	527			0.1
6902000	11/20/1996	4930		3.3	0.18
6902000	1/22/1997	466		1.4	0.07
6902000	2/12/1997	1620		2.2	0.16
6902000	3/17/1997	2510		1.7	0.28
6902000	4/23/1997	29800		4.6	0.28
6902000	5/27/1997	2130		E 2.9	0.44
6902000	6/17/1997	15100		5.2	0.25
6902000	7/29/1997	395			0.12
6902000	8/19/1997	511		0.98	0.18
6902000	9/9/1997	286		1.2	0.15
6902000	11/17/1997	415	6		
6902000	1/15/1998	1590	16		
6902000	6/9/1998	4290	452		
6902000	8/18/1998	587	60		
6902000	11/16/1998	4640	264	1.3	0.15
6902000	12/1/1998	6620		2.4	0.8
6902000	1/25/1999	4150	231	2.4	0.31
6902000	2/23/1999	3040		1.2	0.16
6902000	3/23/1999	2740		3.2	0.25
6902000	4/13/1999	3460		2.5	0.47
6902000	5/19/1999	31900		2.5	0.7
6902000	6/15/1999	6840	1800		
6902000	7/27/1999	429			0.17
6902000	8/10/1999	639	80		0.22
6902000	9/13/1999	365			0.21
6902000	10/26/1999	130			0.1
6902000	11/30/1999	240	10		< 0.05
6902000	12/21/1999	157		0.83	0.06
6902000	1/4/2000	198	16	0.75	0.07

USGS Gage Number	Sample Date	Flow (cfs)	NFR (mg/L)	Total Nitrogen (mg/L)	Total Phosphorus (mg/L)
6902000	2/1/2000	123		0.61	0.05
6902000	3/7/2000	565		1.7	0.27
6902000	4/3/2000	301		0.83	0.19
6902000	5/2/2000	308	95		0.22
6902000	6/12/2000	217			0.22
6902000	7/11/2000	924	180	1.3	0.32
6902000	8/2/2000	465			0.23
6902000	9/12/2000	129			0.22
6902000	10/2/2000	341			0.28
6902000	11/21/2000	220	12	1.2	0.08
6902000	12/5/2000	207		1.3	0.08
6902000	1/3/2001	E 203	< 10	1.5	E 0.03
6902000	2/14/2001	5880		3.3	0.53
6902000	3/6/2001	8040		3.8	0.79
6902000	4/17/2001	7800		3	0.76
6902000	5/1/2001	1740	90		0.22
6902000	6/19/2001	6690		4.7	1.33
6902000	7/10/2001	1830	174	1.2	0.26
6902000	8/13/2001	572			0.17
6902000	9/5/2001	404			0.17
6902000	10/17/2001	3210	555	2.4	0.65
6902000	11/6/2001	416	18		0.1
6902000	12/4/2001	323	16	0.46	0.12
6902000	1/8/2002	179	< 10	0.61	E 0.05
6902000	2/5/2002	347	12	0.95	0.08
6902000	3/6/2002	573	12	0.99	E 0.05
6902000	4/10/2002	4220	1440	3.8	1.16
6902000	5/7/2002	43700	2420	9.1	3.12
6902000	6/10/2002	841			0.2
6902000	7/16/2002	393	145	1.8	0.54
6902000	8/13/2002	175	< 10		0.17
6902000	9/4/2002	145	65		0.18
6902000	10/22/2002	97	39		0.11
6902000	11/27/2002	115	10		0.07
6902000	12/12/2002	102	< 10	0.45	0.05
6902000	2/12/2003	121	< 10	1.3	0.06
6902000	2/25/2003	E 130	< 10	0.52	0.08
6902000	3/21/2003	354	29	0.9	0.09
6902000	4/11/2003	163	46		0.12
6902000	5/2/2003	1940	524	3.3	0.76
6902000	6/20/2003	516	114	2	0.28
6902000	7/29/2003	130	19		0.19
6902000	8/21/2003	66	81		0.23
6902000	9/9/2003	85	58		0.18
6902000	10/21/2003	96	44		0.2
6902000	11/5/2003	75	26		0.09
6902000	12/15/2003	888	89	3.1	0.32

USGS Gage Number	Sample Date	Flow (cfs)	NFR (mg/L)	Total Nitrogen (mg/L)	Total Phosphorus (mg/L)
6902000	1/7/2004	E 275	< 10	1.6	0.08
6902000	2/3/2004	E 165	< 10	1.4	0.08
6902000	3/2/2004	997	112	2.8	0.26
6902000	4/6/2004	2040	136	2.4	0.25
6902000	5/19/2004	21000	1070	8.8	2.37
6902000	6/28/2004	1910	158	1.3	0.28
6902000	7/15/2004	7510	475	3.8	1.22
6902000	8/16/2004	715	49		0.19
6902000	9/2/2004	E 125000	543	1.7	0.57
6902000	10/12/2004	900	132	1.3	0.26
6902000	11/9/2004	1410	56	0.93	0.17
6902000	12/1/2004	813	22	0.86	0.11
6902000	1/24/2005	1530	90	1.8	0.22
6902000	2/14/2005	55000	2160	6.4	1.83
6902000	3/8/2005	1460	43	1.2	0.12
6902000	4/4/2005	992	55		0.11
6902000	5/3/2005	1530	117	1.7	0.21
6902000	6/22/2005	1600	203	1.8	0.34
6902000	7/12/2005	513	135		0.26
6902000	8/22/2005	909	252	1.9	0.41
6902000	9/7/2005	301	55		0.18
6902000	10/12/2005	315	34	1.1	0.12
6902000	11/2/2005	220	< 10	0.54	0.07
6902000	12/19/2005	272	< 10	1	0.04
6902000	1/4/2006	459	14	1.1	0.07
6902000	2/7/2006	357	< 10	0.79	0.07
6902000	3/7/2006	267	12	E 0.44	0.07
6902000	4/10/2006	1010	415	2.7	0.53
6902000	5/3/2006	12500	1180	7.1	1.48
6902000	6/21/2006	386	154		0.3
6902000	7/6/2006	259	41		0.2
6902000	8/2/2006	131	138		0.23
6902000	9/6/2006	432	170		0.34
6902000	10/10/2006	121	51		0.1
6902000	11/6/2006	289	43	1.2	0.15
6902000	12/5/2006	546	76	2.8	0.26
6902000	1/4/2007	3400	767	4.9	1.05
6902000	2/14/2007	272	< 10	1.6	0.05
6902000	3/7/2007	3450	258	3.4	0.48
6902000	4/3/2007	7510	1120	3.9	1.1
6902000	5/2/2007	4620	360	3.4	0.51
6902000	6/6/2007	4600	200	3.1	0.43
6902000	7/10/2007	447	104		0.2
6902000	8/14/2007	1230	242	2	0.37
6902000	9/11/2007	736	52		0.17
6902000	10/23/2007	3100	340	2.9	0.6
6902000	11/6/2007	569	27	1.5	0.12

USGS Gage Number	Sample Date	Flow (cfs)	NFR (mg/L)	Total Nitrogen (mg/L)	Total Phosphorus (mg/L)
6902000	12/4/2007	702	45	0.84	0.14
6902000	1/9/2008	16000	850	3.9	1.11
6902000	2/14/2008	1900	100	1.9	0.22
6902000	3/5/2008	50600	1180	3.9	1.43
6902000	4/16/2008	7050	144	2.8	0.64
6902000	6/2/2008	10700	1120	5.1	1.31
6902000	7/9/2008	4230	384	1.8	0.49
6902000	8/4/2008	8200	452	1.7	0.47
6902000	9/2/2008	803	80		0.16
6902000	10/21/2008	1940	106	1.4	0.27
6902000	11/24/2008	2600	75	1.1	0.15
6902000	12/9/2008	1500	48	0.94	0.11
6902000	2/2/2009	1080	< 15	1	0.06
6902000	3/10/2009	57300	1300	5.9	1.77
6902000	4/1/2009	10900	418	2.3	0.55
6902000	5/5/2009	8690	780	2.5	0.68
6902000	6/2/2009	3960	312	2.9	0.42
6902000	7/28/2009	986	62		0.18
6902000	8/17/2009	46900	1790	3.9	1.52
6902000	9/1/2009	6300	454	1.7	0.53
Mussel Fork near Mystic, MO					
6905725	1/23/1998	1.6	12		
6905725	6/3/1998	1.2	22		
6905725	1/6/1999	1.9	4	0.56	< 0.05
6905725	3/31/1999	2.4		0.54	E 0.04
6905725	4/21/1999	8.4		0.98	0.11
6905725	6/23/1999	0.54	47	0.89	0.09
6905725	10/25/1999	0.01			0.07
6905725	11/30/1999	0.01	11		0.05
6905725	12/20/1999	0.1			< 0.05
6905725	1/24/2000	0.1	24		0.05
6905725	4/20/2000	0.16			0.07
6905725	5/11/2000	0.07	< 10		0.07
6905725	6/14/2000	8.3		3.3	0.44
6905725	6/15/2000	7.3		2.7	0.25
6905725	6/20/2000	0.22		1.9	0.11
6905725	7/27/2000	0	10		E 0.04
6905725	10/25/2000	0.03			0.28
6905725	11/15/2000	0.1	< 10		0.08
6905725	12/20/2000	0.02			0.06
6905725	1/24/2001	0.24	10	4.3	0.17
6905725	2/14/2001	59		3.2	0.42
6905725	3/28/2001	4.3		2.2	0.12
6905725	4/25/2001	4.1			0.12
6905725	5/22/2001	1.1		1.1	0.08
6905725	5/23/2001	0.82	11	1.1	0.08
6905725	6/18/2001	7.6		1.4	0.21

USGS Gage Number	Sample Date	Flow (cfs)	NFR (mg/L)	Total Nitrogen (mg/L)	Total Phosphorus (mg/L)
6905725	6/28/2001	2.5			0.11
6905725	7/26/2001	4.8	228	4.7	0.4
6905725	8/9/2001	0.13		E 1.1	0.1
6905725	9/11/2001	0.03		E 1.1	0.1
6905725	10/24/2001	3.5	50	2.4	0.42
6905725	11/29/2001	0.17	< 10		E 0.06
6905725	12/13/2001	0.83	20		E 0.05
6905725	1/9/2002	0.2	10	0.97	E 0.05
6905725	2/28/2002	1.4	18	1.4	0.09
6905725	3/20/2002	0.97	< 10		E 0.04
6905725	4/18/2002	1.6	17		0.07
6905725	5/22/2002	2.2	20		0.12
6905725	6/27/2002	0.06	10	E 0.69	E 0.04
6905725	8/22/2002	0.17	22	E 0.77	0.08
6905725	2/21/2003	0.05	< 10	1.7	0.15
6905725	3/13/2003	2.5	37		0.2
6905725	3/19/2003	0.3	14	E 1.7	0.14
6905725	4/24/2003	0.19	26	1.9	0.1
6905725	4/30/2003	1.9	32	2.2	0.2
6905725	5/7/2003	2.5	44	2.1	0.23
6905725	6/12/2003	0.72	16	E 1.2	0.09
6905725	7/9/2003	E 0.00	11		0.1
6905725	9/17/2003	0.33	15	1.7	0.14
6905725	11/19/2003	E 0.01	38		0.27
6905725	12/11/2003	7.9	84	5	0.41
6905725	1/8/2004	0.24	19	2.1	0.17
6905725	2/20/2004	41	81	3.5	0.52
6905725	3/17/2004	25	60	1.8	0.18
6905725	4/21/2004	1.6	15		0.06
6905725	5/12/2004	0.55	< 10		0.07
6905725	6/24/2004	1.9	31	1.6	0.21
6905725	7/13/2004	11	52	1.6	0.21
6905725	8/24/2004	0.25	21	1.1	0.07
6905725	9/15/2004	0.52	< 10	E 1.1	0.09
6905725	10/28/2004	2	< 10		0.14
6905725	11/17/2004	1.8	< 10	0.67	0.06
6905725	12/17/2004	2.4	< 10	0.71	0.05
6905725	1/26/2005	18	46	1.8	0.22
6905725	2/8/2005	22	65	2.6	0.18
6905725	3/17/2005	2.9	< 10		0.13
6905725	4/7/2005	2.9	< 10		0.06
6905725	5/11/2005	11	10		0.07
6905725	6/29/2005	1.7	21		0.08
6905725	7/14/2005	0.02	< 10		0.04
6905725	8/18/2005	0.08	22	E 1.8	0.12
6905725	9/21/2005	0.05	74		0.23
6905725	10/4/2005	0.9	316	4.2	0.59

USGS Gage Number	Sample Date	Flow (cfs)	NFR (mg/L)	Total Nitrogen (mg/L)	Total Phosphorus (mg/L)
6905725	11/1/2005	0.04	22		0.16
6905725	12/13/2005	0.01	< 10		0.06
6905725	1/27/2006	0.12	< 10		0.05
6905725	2/15/2006	0.17	15	2.9	0.07
6905725	3/9/2006	0.3	< 10		0.04
6905725	4/14/2006	1.3	18		0.08
6905725	5/12/2006	1.1	10		0.07
6905725	6/15/2006	0.11	< 10		0.06
6905725	7/17/2006	0	34	1.5	0.15
6905725	8/8/2006	2.4	203	1.9	0.36
6905725	9/21/2006	0.06	11	1.1	0.06
6905725	10/23/2006	0.03	20	2.1	0.14
6905725	11/15/2006	0.03	82		0.2
6905725	12/15/2006	0.2	< 10	0.95	0.1
6905725	1/24/2007	0.62	11	1	0.1
6905725	2/22/2007	8	< 10	4.4	0.58
6905725	3/13/2007	6.5	25	2.3	0.17
6905725	4/24/2007	1.7	< 50		0.08
6905725	5/8/2007	74	176	2	0.36
6905725	6/28/2007	12	444	5.6	0.6
6905725	7/17/2007	0.06	26		0.08
6905725	8/22/2007	2.5	245	3.5	0.53
6905725	9/26/2007	0.04	54		0.18
6905725	10/17/2007	0.07	312	1.9	0.37
6905725	11/7/2007	0.05	11		0.16
6905725	12/18/2007	2.8	20	2.5	0.2
6905725	1/9/2008	40	68	3.1	0.28
6905725	2/26/2008	39	180	3.1	0.57
6905725	3/25/2008	6.2	21	1.4	0.1
6905725	4/17/2008	5.8	28	1.1	0.11
6905725	5/22/2008	1.2	10		0.07
6905725	6/19/2008	2.5	25	1.5	0.15
6905725	7/18/2008	0.4	16		0.1
6905725	8/14/2008	3.9	182	1.9	0.28
6905725	9/23/2008	2.1	14		0.12
6905725	10/28/2008	1.5	< 15	1.3	0.12
6905725	11/20/2008	4.8	< 15	1.3	0.1
6905725	12/4/2008	3.5	< 15	0.6	0.05
6905725	1/29/2009	0.89	< 15	0.62	0.06
6905725	2/26/2009	4.8	< 15	0.62	0.05
6905725	3/12/2009	25	170	2.3	0.28
6905725	4/23/2009	5.4	< 15	E 0.64	0.07
6905725	5/14/2009	47	214	2.4	0.34
6905725	6/26/2009	5	< 150	1.8	0.16
6905725	7/21/2009	0.32	< 15		0.05
6905725	8/19/2009	2	106	2.1	0.23